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ENHANCEMENT OF PHOTOLOG APPLICATIONS AND DISPLAY ENVIRONMENT

Final Report
June 1999

University of Connecticut

School of Engineering

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ENHANCEMENT OF PHOTOLOG APPLICATIONS AND DISPLAY ENVIRONMENT

Final Report
June 1999

JHR 99-269 Project 97-3

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16. Abstract

A survey of users of the Ground Based Image and Data Acquisition System ("photolog") in the Connecticut Department of Transportation (CONNDOT) has shown it to be a valuable, cost-effective resource. Since its inception in the early 1970s when it was used primarily to enhance the inventory process, it has evolved into a sophisticated system used routinely by a wide variety of units within CONNDOT. Increasingly, uses outside ConnDOT are developing and the technology may be on the verge of serving the state in economic development and tourism. Important specific needs expressed by current CONNDOT users include increasing the vertical field of vision and providing access via a LAN. Integration of the various other databases developed by the ARAN vehicles and display in the formats given in the report will also be quite valuable. It is strongly recommended that crash data, by year, should be included in the proposed series of screens.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	mililitres	mL
gal	gallons	3.785	Litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

* SI is the symbol for the International System of Measurement

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C+32	Fahrenheit temperature	°F

°F 32 98.6 212 °F
-40 0 40 80 120 180 200
-40 -20 0 20 40 60 80 100
°C 37 °C

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FIGURES AND TABLES

INTRODUCTION

1.1 Background

The Connecticut Department of Transportation (CONNDOT) has the responsibility of planning, constructing, and maintaining over 3800 miles of highways. The discharging of these responsibilities requires a wide range of technical and administrative expertise. The approximately 3500 employees of the Department are assigned to operating units which are organized as shown in Figure 1. They reside at the main administrative building in Newington, at various District offices, maintenance facilities, and miscellaneous other facilities throughout the state. While the specific responsibilities differ between each of the functional areas, ultimately the focus is primarily on the roadway system. As with all state departments of transportation, one of CONNDOT's greatest challenges is to maintain and efficiently organize a number of large, disparate databases. To maintain efficiency, data must be reliable and readily accessible in the appropriate format to many users. The photolog program offers one effective means of integrating the databases. The purpose of the study described herein was to examine how the program is currently performing this integrative function, suggest ways it might be improved, and identify potential new users.

1.2 Outline of the Report

Following this introduction, the report describes the current system and its evolution. Next, the overall procedure is described, followed by descriptions of existing uses and users. Possible new uses are then proposed for consideration. Finally, conclusions and recommendations are presented.

2. THE GROUND-BASED IMAGE AND DATA ACQUISITION SYSTEM (PHOTOLOG)

The Ground-based Imaging and Data Acquisition System, commonly referred to as the photolog, was begun by CONNDOT in the early 1970's. Over the years it has evolved into a highly sophisticated system which is widely used by many units in the Department and by the public. Today, CONNDOT is arguably the national leader in the application of this technology.

Two vehicles annually photolog the 3800-mile state highway system, all ramps, and the CT Transit bus system bidirectionally. Originally, images were captured onto 35-mm color film at 0.01-mile intervals. These were then transferred onto 35-mm strip film and subsequently edited onto small reels.[1] The process was significantly improved in early 1985 when a PC-based image retrieval system was introduced. Although that system was found to be cost effective for high levels of usage, it was expensive (approximately $31,000 for a fully configured system), required a 4 x 6-ft tabletop, and utilized hardware that had been discontinued by the manufacturer.

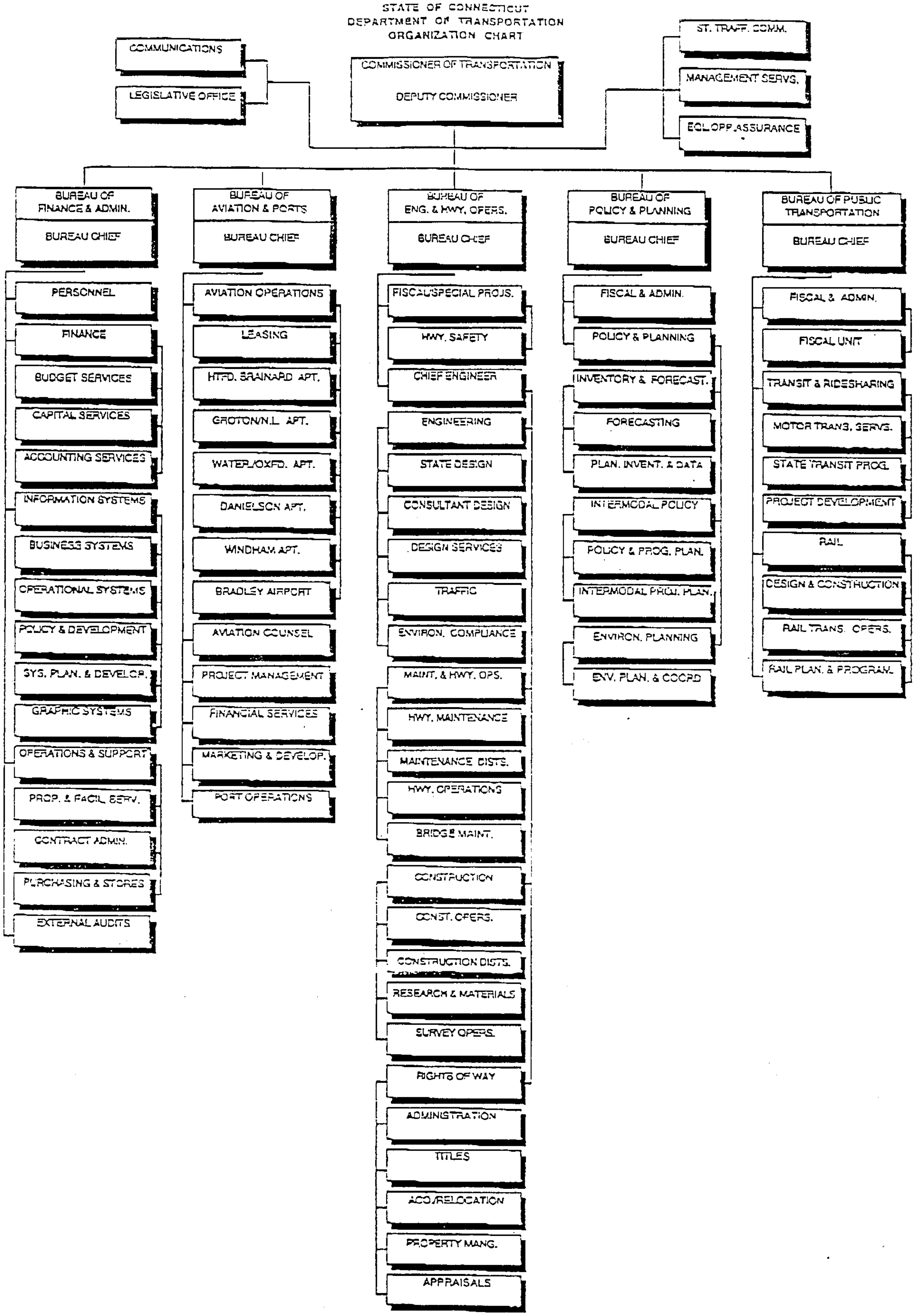


Figure 1: Connecticut DOT Organizational Chart

The present (1998) "mini-PLV" system is much cheaper and user friendly than the 1985 system. Photologging is done using two Automatic Road Analysis (ARAN) systems. ARAN 5, the more complete system, is shown in Figures 2 through 8. It is equipped with the following:[2]

- forward- and side-pointing progressive scan digital cameras
- downward-pointing pavement imaging system (WISECRAX)
- data modules:
  - Real-Time Differential Geographic Positioning System (DGPS)
  - roadway geometrics (horizontal and vertical curvature)
  - grade
  - crossfall
  - rutting
  - roughness (IRI)

The entire state-maintained roadway system (including ramps) has been transferred to 13 double-sided photolog laser videodiscs, indexed, and videolinked. Video linking ensures consistent linear referencing from year to year.

3. EXISTING USES

3.1 CONNDOT

A list of persons and units who have used the system was obtained from the Division of Research. These people were then interviewed to determine:

- The nature of the use of the system
- Suggestions for improvement of the system
- Interest in further uses

The following persons were interviewed (in alphabetical order):

- Julie Annino (Traffic)
- Glen Artz (Engineering)
- Eduardo Block (Pavement Management)
- David Cruz (Incident Management)
- John Durling (Rights of Way)
- Eric Glover (Planning Inventory and Data)
- Keith Hayden (Pavement Management)
- Tom Iacobucci (Incident Management)
- Joseph Misbach (Maintenance)

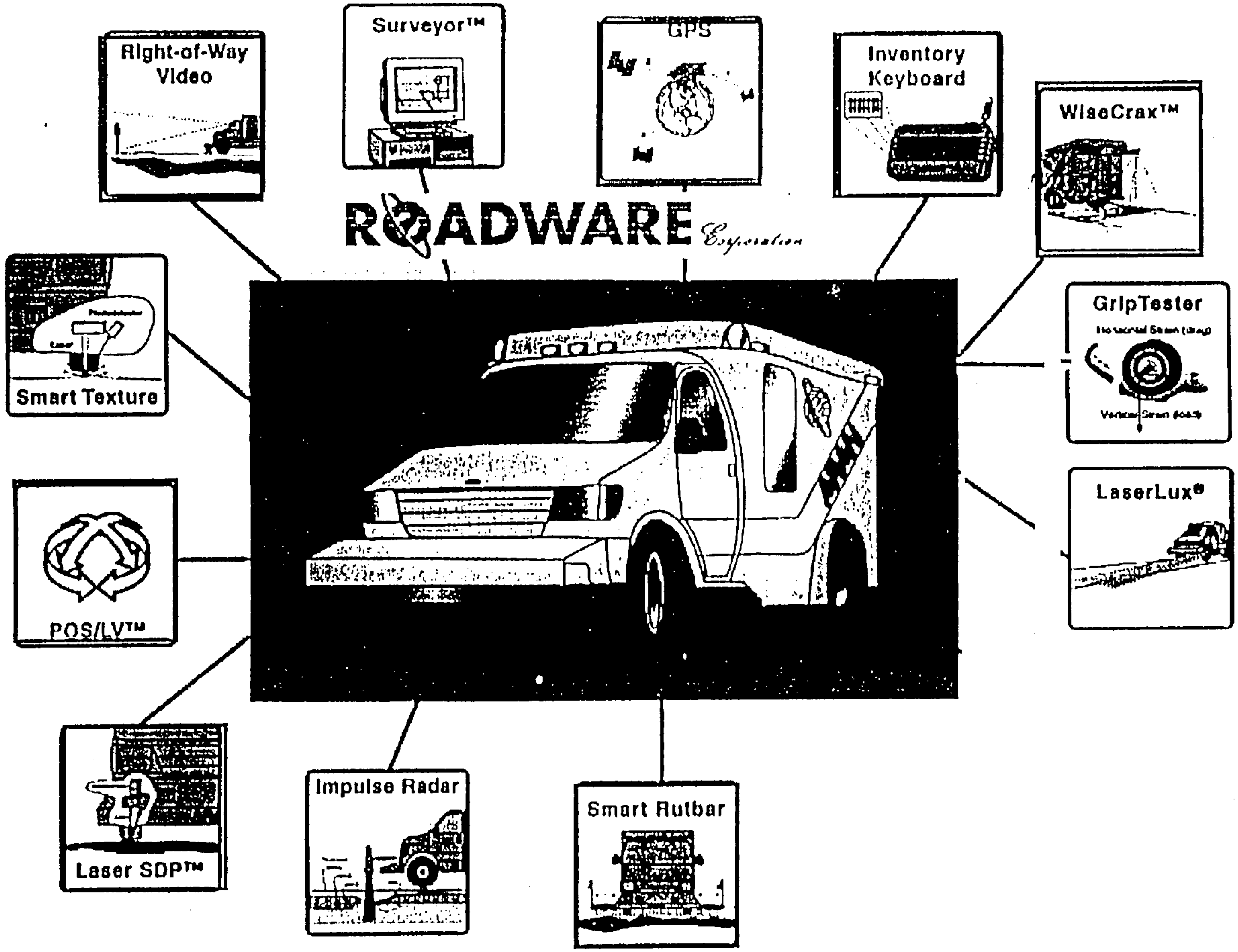


Figure 2: ConnDOT Aran Vehicle #5

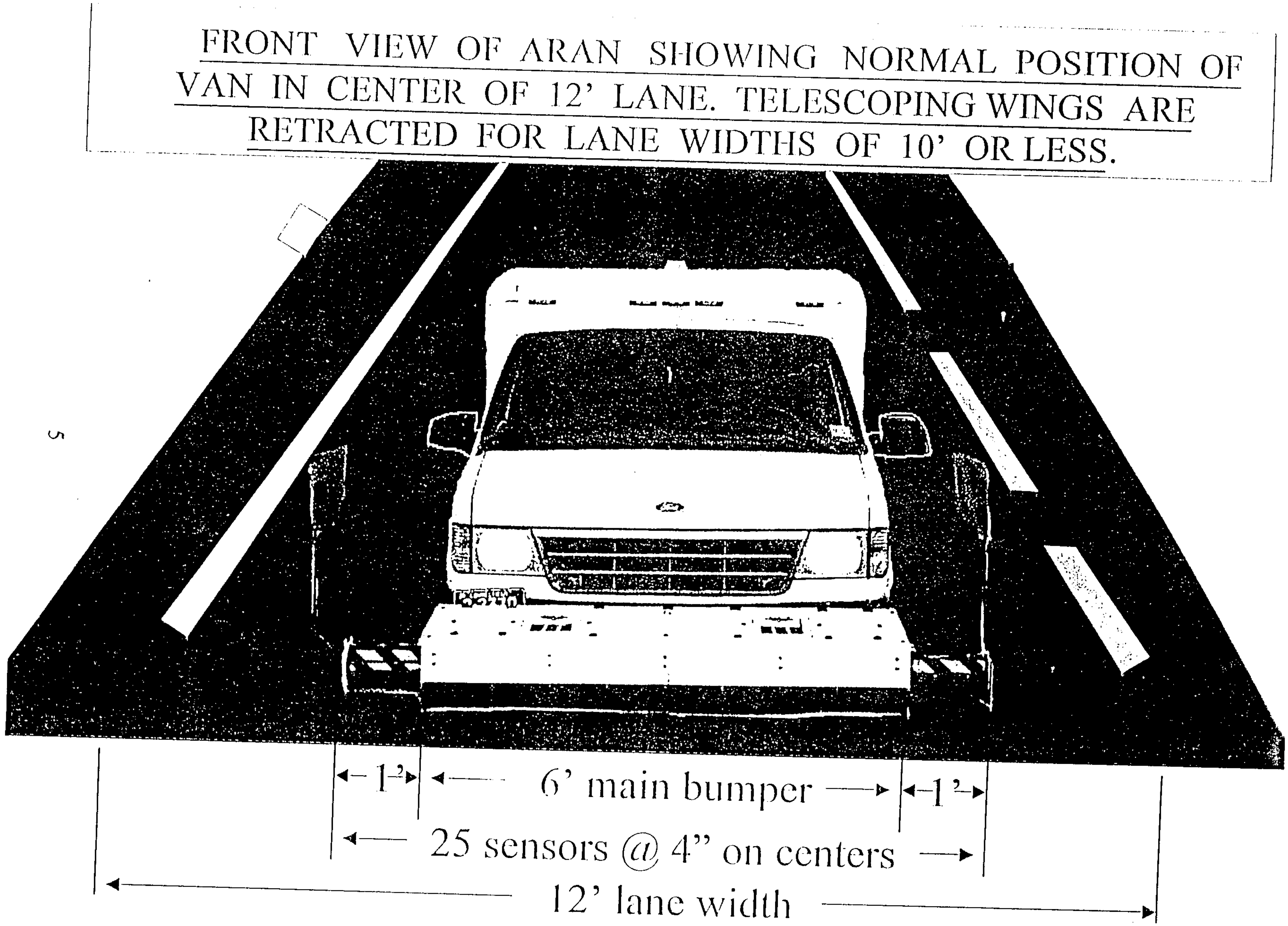


Figure 3: Front View of Aran Vehicle

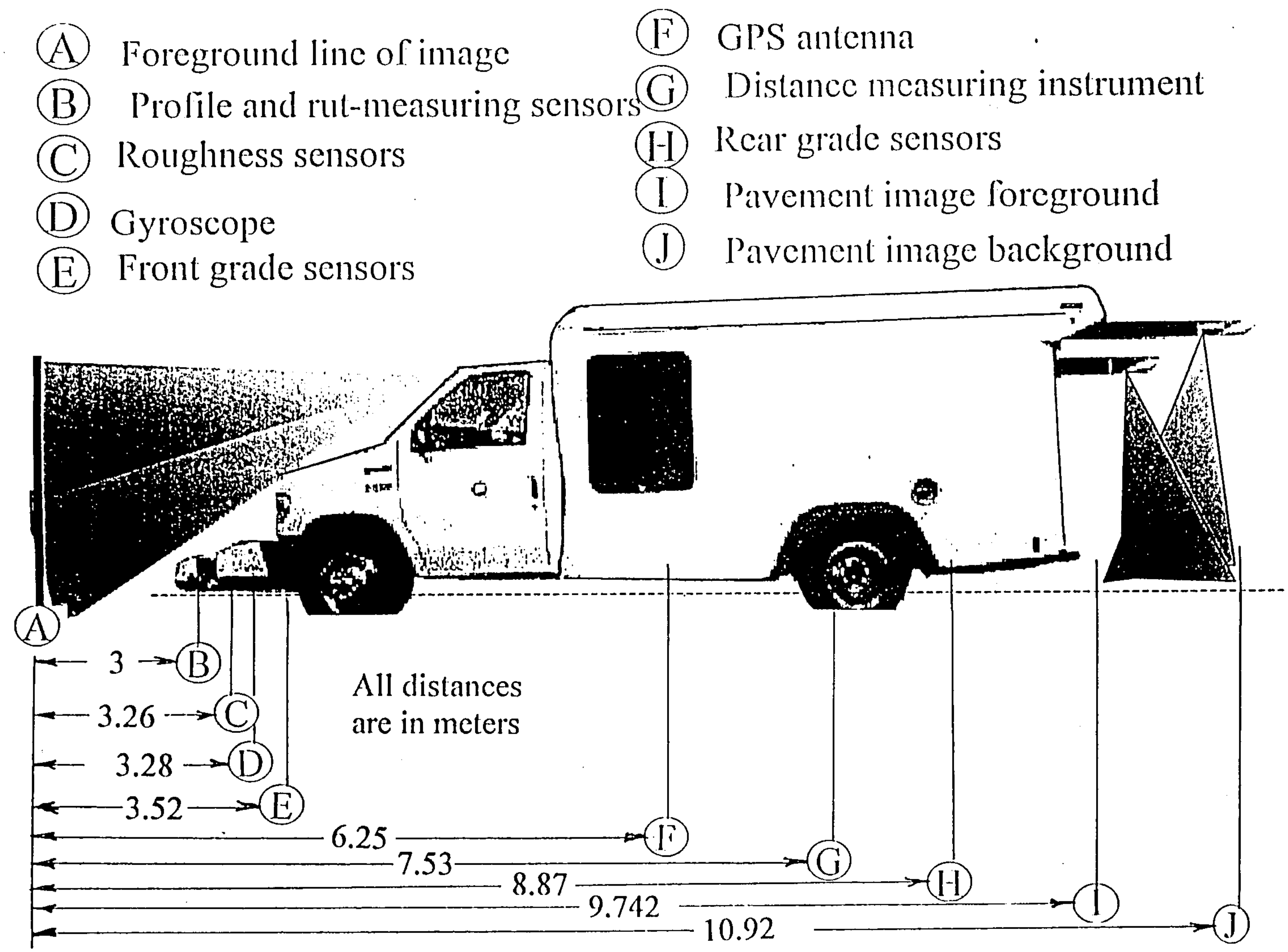


Figure 4: Imaging and On-Board Sensor Relationships

RELATIONSHIP BETWEEN FOREGROUND LINE OF IMAGE AND LOCATION OF PROFILE OVER WHICH CORRESPONDING ROUGHNESS VALUE IS OBTAINED

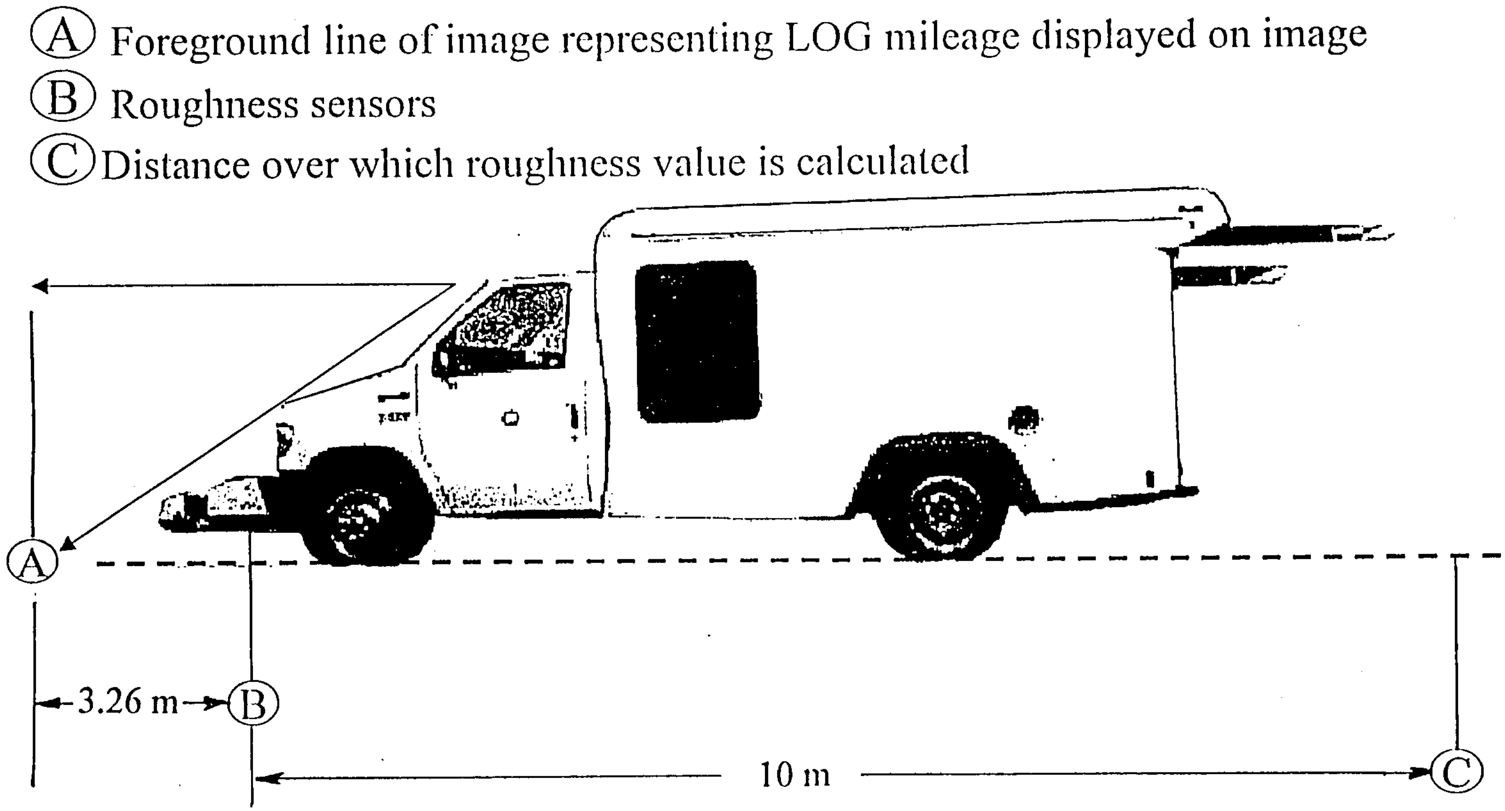


Figure 5: **Relationship between Foreground Line of Image and Location of Profile over which Corresponding Roughness Value is Obtained**

RELATIONSHIP BETWEEN FOREGROUND LINE OF IMAGE AND LOCATION OF POINTS BETWEEN WHICH GRADE VALUE IS OBTAINED

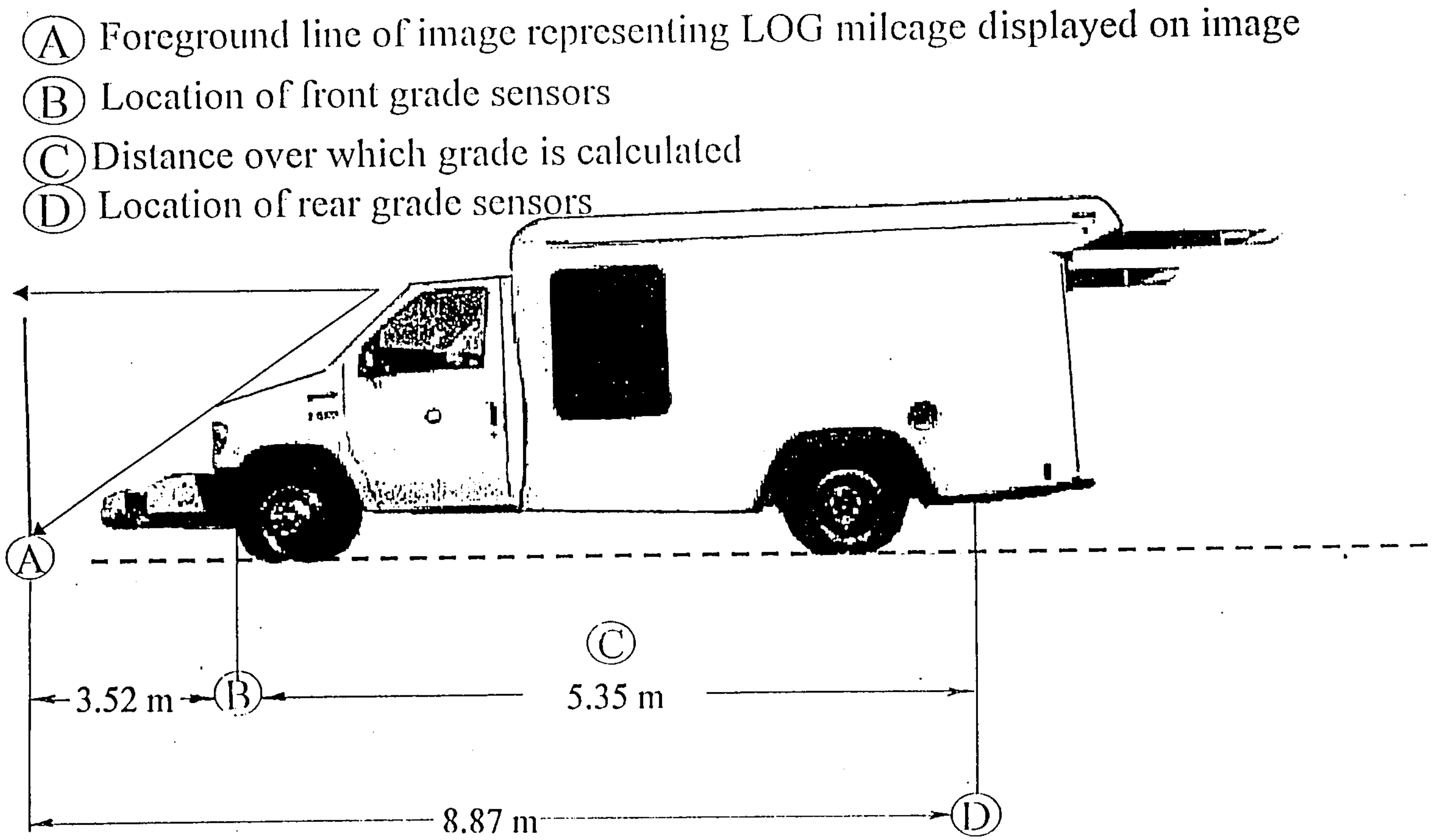


Figure 6: **Relationship between Foreground Line of Image and Location of Points between which Grade Value is Obtained**

RELATIONSHIP BETWEEN FOREGROUND LINE OF IMAGE AND LOCATION OF GPS RECEIVER FOR WHICH GPS COORDINATES ARE CALCULATED

(A) Foreground line of image representing LOG mileage displayed on image

(B) Location of GPS receiver antenna

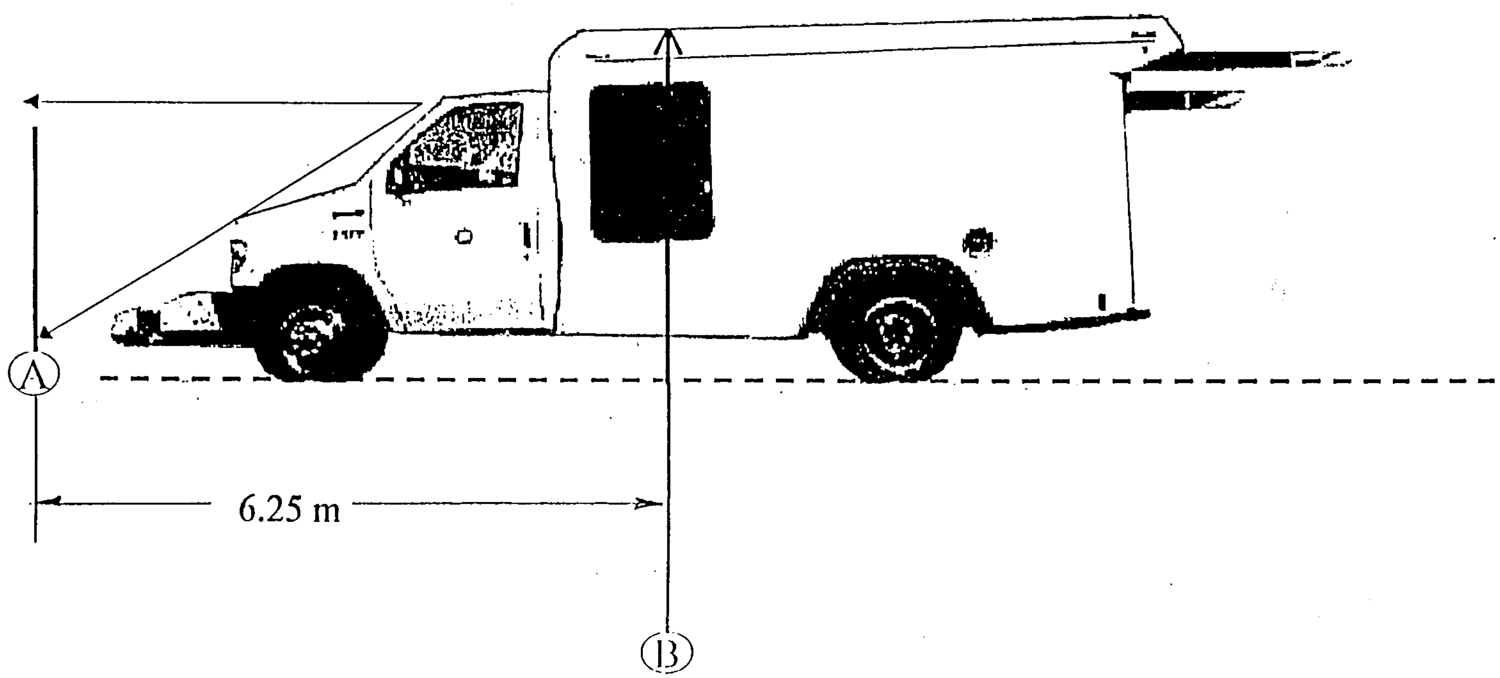


Figure 7: **Relationship between Foreground Line of Image and Location of GPS Receiver for which GPS Coordinates are Calculated**

RELATIONSHIP BETWEEN FOREGROUND LINE OF IMAGE AND LOCATION OF TRANSVERSE LINE ALONG WHICH PROFILE, RUTTING, AND CROSS-SLOPE ARE MEASURED AND CALCULATED

(A) Foreground line of image representing LOG mileage displayed on image

(B) Point at which transverse profile, rut depths, and cross-slope are measured and or calculated

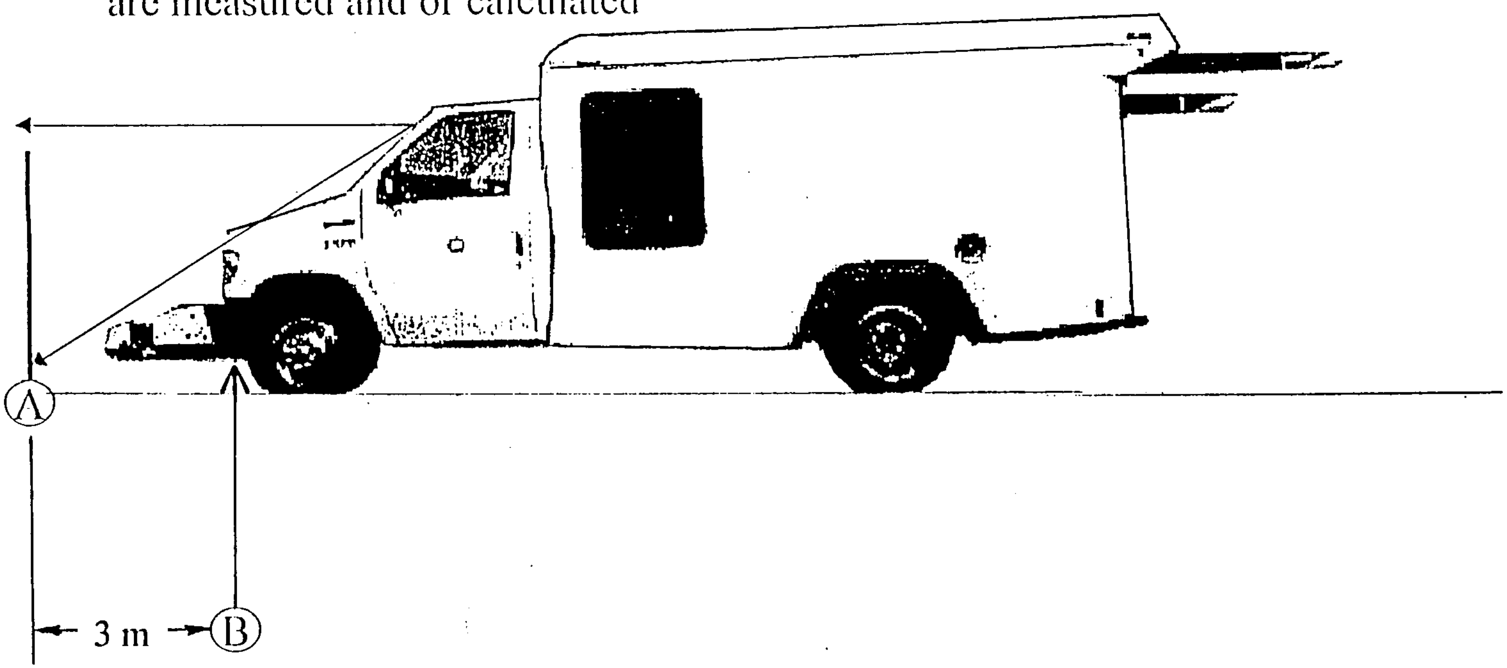


Figure 8: **Relationship between Foreground Line of Image and Location of Transverse Line along which Profile, Rutting, and Cross-Slope are Measured and Calculated**

- Michelle Nolfi (Engineering)
- Robert Ramirez (Federal Highway Administration)
- John Rinaldi (Central Surveys)
- Erica Smith (Traffic)

Summaries of these interviews are presented in Appendix A. A synopsis is given below.

The ***Division of Traffic*** is one of the greatest users of the system. It is used to determine, among other things, sight distance, nature of area development, and illumination in traffic generator studies. Significant use also occurs in sign studies, measurement of stopping sight distance, and horizontal curvature. Examination of right-of way widths and determination of the presence and type of guiderail are also frequent uses. A use that one might not think of is in the determination of the date of signal installation so that the appropriate utility company can be paid.

As might be expected ***Engineering*** makes considerable use of the photolog. Again, guiderail studies loom large, but the system is also useful in miscellaneous other studies such as edge-of-pavement drop-off and curbing.

The features of the system most used by *Pavement Management* deal with pavement distress and cross slope. In this connection, the WISECRAX software has been found to be helpful.

Highway Operations makes extensive use of the photolog in reviewing diversionary routes for incident management and reviewing routing for oversize/overweight loads.

Planning Inventory and Data uses the system on a daily basis. The primary use by this group is in examining entrances in connection with major generator studies. It also is of operational value when directing field crews where to set up automatic traffic recorders as well as route mile file re-inventory. The ***Systems Inventory Unit*** also makes heavy use of the photolog as part of the development of data for the roadway inventory and Highway Performance Monitoring System (HPMS) files. In addition, this unit utilizes IRI, vertical curve and grade statistics.

The *Division of Rights of Way* has integrated the photolog with a GIS and the combination has proved to be extremely valuable in the inventory of excess land, widening, and in a study of billboards.

The *Division of Maintenance* uses the system in numerous ways. Chief among these establishing pavement ratings. The system is also used to establish homogeneous pavement sections for making the ratings. Other uses include: providing a record of maintenance actions, reviewing pavements in response to complaints from the public, providing background in litigation, and rail upgrading.

Central Surveys uses the photolog for reconnaissance for traverses. In particular, it provides information on shoulder widths, side slopes, and roadway grades. Another major use is to evaluate potential sites for Global Positioning System (GPS) observations.

The Division Office of the *Federal Highway Administration* has found, as have most other users, that the technology has a great value in reducing field trips. The historic record provided by the photolog allows certification inspection to occur closer to the date of physical completion of construction.

3.2 UCONN

The system has been, and continues to be, heavily used at the Connecticut Transportation Institute of the University of Connecticut. Both uses involve highway safety studies.

The first use is in connection with Project 97-1 and is described in an interim report[3]. Briefly, the study consists of identifying benefits associated with safety improvements. Much of the site information required for the work was collected using the photolog. The characteristics collected included lane and shoulder widths, number of roadside objects (buildings, utility poles, mailboxes, trees) within a certain distance from the traveled way, number of driveways by type, number of minor intersections, roadway lighting conditions, traffic control devices, number of approach legs, sight distances from the intersection, type and visibility of warning devices, and presence of guide-rail and their type and end treatment. It is anticipated that the new side view feature will be quite valuable in subsequent work.

The other use is a study of the ability of drivers to assess the relative "hazard" presented by a variety of highway conditions for which the historic crash rate is known. While the study is only partially complete at this time, it is clear that the photolog has much to offer. With regard to the study itself, preliminary results suggest that novice drivers are relatively poor judges of road hazards. Interestingly, persons who have experienced more accidents tend to be more accurate in their judgements.

4. SUGGESTED IMPROVEMENTS, AND NEW FEATURES AND USES

4.1 Desired Features

Findings and recommendations from this study are summarized in Table 1. Note that part a of the table is devoted to CONNDOT uses, while part b covers other users. Both existing and potential (shaded) users are identified. Also given for each entry are estimates of the value of the given feature for the given user. Obviously, the accuracy of these estimates varies with the particular feature/user combination.

It is clear that the photolog is a valuable tool with many uses. The interviews with existing users consistently point to the following enhancements:

Table 1a - ConnDOT Users

	Image	Video	Side View	Vertical Angle	Night Images	Grids	LAN	Auto Comps	Training	Horiz Curvature	Vert Curvature	Grade	Cross-fall	Rutting	Ride Number	Lat/Long	Elevation	Roughness	Texture
Aviation and Ports																			
Bradley Airport	M		M		L		L												
Port Operations	M		M																
Engrg and Hwy Ops																			
Highway Safety	M		M		L				H										
State Design	H		H	M		M			H	H	H	H	H	L	L	H	M	L	L
Consultant Design	M	L	M	M		M			H	H	H	H	H	L	L	H	M	L	L
Design Services	L	L	L	M		M			H	H	H	H	H	L	L	H	M	L	L
Traffic	H	H	H	H	M	M	H	H	H	H	H	H	H	L	L	H	M	L	M
Environmental Compliance	M	M	M																
Highway Maintenance	H	M	H	L	M	M	H	L	M	L	L	L	L	H	H	H	L	H	M
Maintenance Districts	H	M	H	L	M	M	H	L	M	L	L	L	L	H	H	H	L	H	M
Highway Operations	H	L	H	H	M	M	H	L	H							H			
Bridge Maintenance	H	M	M	H		H	H									H			
Construction	M		M	M		M	H		M	L	L	L	L						
Construction Operations	M		M	M		M	H		M	L	L	L	L						
Construction Districts	M		M	M		M	H		M	L	L	L	L						
Research and Materials	M	M	M	M	M	M	H	M	M	M	M	M	M	M	M	M	M	M	M
Survey Operations	M	M	H			M	M									H			
Titles																			
Aco/Relocation	H		H			H													
Property Management	M		M			M													
Appraisals	H		H			H													
Policy and Planning																			
Planning Invent. and Data	H	H	H	L	L	H	H		M	H	H	H				H			
Intermodal Proj Planning	M		M																
Environmental Planning	M		M																
Public Transportation																			
Motor Transp. Services	M		M																
Project Development	M		M																
Rail Design and Construction	M		M																
Rail Transp Operations																			
Rail Plan & Programming	M		M																

Key: Potential User: [shaded]
Value of Feature: H (high), M (medium), L (low)

Table 1b - Other Users

	Image	Video	Side View	Vertical Angle	Night Images	Grids	LAN	Auto Comps	Training	Horiz Curvature	Vert Curvature	Grade	Cross-fall	Rutting	Ride Number	Lat/Long	Elevation	Roughness	Texture
FHWA	H	M	H	H	M	H	H		H	M	M	M	M	M	M	M	M	M	M
UCONN																			
CT Transp Institute	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Babbidge Library	H	H	H	M	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
State Police	H		H						M							H			
DMV	M		M	H		M			H							H			
DEP	M		M			M										H			
DECD																			
Site Selection	H	M	H													H			
Tourism ("Quick Trips")	H	M	H													H			
Siting Council	H	M	H													H			
DPW (sale of State propert)	H	M	H													H			
General Public	H		H																

Key: Potential User: [shaded]
Value of Feature: H (high), M (medium), L (low)

- Provision of network access
- Side views
- Availability of continuous medium.
- Increased vertical angle
- Integration with GIS
- Integration of crash data and bridge information system

In the review of the draft of this report, the request was made to provide the capability of measuring vertical clearances to within three inches to satisfy the needs of those responsible for permitting over-dimensional vehicles. A panoramic view would also be very helpful to this unit.

With continually increasingly efficient network capability, it is simply a matter of time before access to the system can be increased to new users directly to their own PCs. It is our understanding that CONNDOT is moving in this direction and that the capability will exist in a few years. While an assessment of hardware and software capabilities is beyond the scope of this report, based on our work, providing access via a local area network should be a high priority. It is recognized that this is no small task. A data transfer capability on the order of 100 megabits coupled with the ability to remotely access a "jukebox" with the appropriate discs would probably be required. Obviously, such an increase in accessibility will accrue to users who currently do not have a mini-PLV. In addition, staff who now have a station in their general work area will be more inclined to use the system if it can be accessed directly from their personal computers. Finally, as discussed more completely below, there exists a large number of potential users outside CONNDOT who could benefit from access via the Internet. In such cases, the data transfer limitations are even more severe and it would likely be that only very selected image data would be transferred.

Improvement of the screens themselves has been the subject of extensive work by CONNDOT and its consultants. Mock-ups of the most recent series and their descriptions are given in Appendix B. Note that several users expressed strong interest in having bridge information and crash data included in these screens.

Given the historical development of the photolog, and its early uses in pavement management, it is not surprising that enhancements have concentrated on the forward-facing images. With many of the more recent uses, however, the lateral views are of increasing importance and should prove very cost-effective. A number of the newer uses and uses proposed herein have their primary orientation directed to the roadside rather than the roadway itself. Existing uses in this category include observation of roadside development, evaluation of abutting properties, billboard studies, and safety studies.

The availability of a continuous medium (the original video) would be attractive to several users who find the discretization at 10-m intervals makes it difficult to accurately identify some features such as small signs. It is likely that this feature will not easily be implemented in a LAN environment, and the problem with inter-frame viewing might be largely eliminated with the introduction of the side facing views. Use of the video would also be valuable in "simulator" studies at the University of Connecticut and in training applications.

The need for an increase in the vertical angle was expressed by two groups of users. The Division of Traffic would find it helpful in viewing luminaires and the Incident Management group would use it in reviewing vertical clearances along diversionary routes. It is likely that other groups would also find this to be a valuable feature.

Integration of the photolog with a GIS is a natural enhancement, which was recognized early by at least one vendor (Transcad). The coupling of these two technologies would create an extremely powerful integration of the various disparate databases used by CONNDOT. It has already been somewhat accomplished by the Division of Rights of Way, and its continued development should be pursued.

4.2 New Uses and Users

The Principal Investigator of the present study is part of a **UConn** team, which has received funding from the USDOT to develop visualization tools for teaching highway design. Specifically, the project will use the photolog images as the basis for developing dynamic, 3-D models of selected geometric elements. The output of the work will be an interactive visualization toolbox, which will enable a user to select a highway section that is characterized by specific geometric design features. Once this highway section is selected the user will be able to simulate a drive over the section at any desired speed. The goal is to provide the user with a method for fully visualizing the implications of different design options. Such a capability is of increasing importance given recent federal level policy initiatives such as the recent FHWA publication, Flexibility *in Highway Design.*[4] It is suggested that the resulting toolbox will also be of benefit in on-the-job training of junior level ConnDOT engineers. Even without the toolbox, the photolog provides an ideal medium for training and such use should be aggressively pursued. In this regard, the Local Transportation Assistance Program (LTAP) of the Connecticut Transportation Institute plans to utilize both the images and associated geometric data in its program of training local highway personnel.

As noted in Table 1a, there are numerous other potential users outside of CONNDOT. Perhaps the most logical of these is the **Babbidge Library** on the Storrs campus of the University of Connecticut. The library would be a singularly hospitable environment, not only because of its public visibility, but also because of the technology-oriented mindset of its administration.

Two other agencies, the **State Police** and the **Department of Motor Vehicles** should both find the opportunities for training attractive. A station was installed at State Police headquarters in March of 1999. The **Department of Community and Economic Development** would find the images of value in their "Site Selection" and tourism programs. For example, the tourism web page leads to "Quick trips" wherein numerous categories are displayed. It would appear that it would be relatively easy to hyper-link text referring to scenic roads, for example. Such views could also be made available to the **general public** through kiosks in roadside rest areas, airports, and other key locations. The side-facing views would be of similar interest to the State **Siting Council** and the **Department of Public Works** (for sale of State property).

5. CONCLUSIONS

The photolog has proven to be a valuable, cost-effective resource for ConnDOT. Since its inception in the early 1970s when it was used primarily in connection with physical inventory enhancement, it has evolved into a sophisticated system used routinely by a wide variety of units within CONNDOT. Photolog images are used for purposes of review, measurement, confirmation, and documentation. All occasions of usage are logged. A quarterly review of usage is undertaken to determine: (1) was a field trip eliminated, or (2) was less time spent in the field? If either of these conditions applies then (3) reduced fleet vehicle usage, and (4) gasoline consumption occurs. Currently these four instances save an estimated $800,000 annually.

Increasingly, uses outside CONNDOT are developing and the technology may be on the verge of serving the state in economic development and tourism. Important specific needs expressed by current CONNDOT users include increasing the vertical field of vision and providing access via a LAN. Integration of the various other databases developed by the ARAN vehicles and display in the formats shown in Appendix B will also be quite valuable.

Finally, it is strongly recommended that crash data, by year, should be included in the proposed series of screens.

REFERENCES

[1] "ConnDOT Uses Laser Videodiscs in Photologging", *TRNews*, September-October 1986. Transportation Research Board, Washington, D.C., pp. 20-21.

[2] ConnDOT Division of Research Work Plan, p. 37.

[3] Yuan, F., Ivan, J .N., Davis, C. F. and N. W. Garrick. Estimating Benefits from Highway Safety Improvements: Phase I – Feasibility Study. Draft report, Project 97-1, Oct. 1998

[4] Federal Highway Administration, *Flexibility in Highway Design*. 193 pp. No date.

APPENDIX A

SUMMARIES OF INTERVIEWS

1. Traffic

   Interview date: 5/29/98. Persons interviewed: Julie Annino and Erica Smith.
   Uses and comments:
   - "Scenic Roads" designation
   - Expressway signing (especially Exit Signing)
   - Intersection sight distance evaluation
   - Service signing
   - Stopping sight distance
   - Horizontal curvature
   - Traffic Generator Studies
     - Sight distance
     - Nature of area development
     - Illumination studies (in cooperation with the illumination group). The observation was made that a steeper vehicle angle would assist in the accurate determination of existing luminaires.
   - Exit ramps
   - Traffic signals

     This is a good example of an important use that is, perhaps, unanticipated. It consists of determining when a signal was installed so that the appropriate utility company can be correctly paid.
   - Guiderail

     The photolog is often used by Traffic to determine whether, and what type guiderail was/is present at a specific location.
   - Right of Way

     The width of right of way is important to Traffic as to other units. One specific example is in the determination of how much brush can be removed so that sight lines can be improved.
   - General comments and suggestions

     Have been using for over 10 years
     Night views would be useful
     Lens angle should be greater
     Side views will help
     Frame spacing is important so as not to miss smaller signs
     Mileage doesn't always match the mileage log
     Grids are not "that" accurate
     Need greater accuracy for measuring pavement markings and shoulder width

2. Engineering

   Interview date: 5/29/98. Person interviewed: Glen Artz

Uses and comments:
- Identification of needed guiderail replacement
- Side view will be helpful
- Curbing
- Drop-off of edge of pavement
- Would be helpful to have direct access from regular CAD stations
- Has been using for 5 years

Interview date: 5/29/98. Person interviewed: Michelle Nolfi
Uses and comments:
- Study upgrading of guiderail. Engineering has been charged with the task of developing a policy and procedure for upgrading. (Michelle is writing)
- Construction people are available to survey
- Photolog gives an on-line inventory
- Including ramps improves the inventory
- A guiderail inventory program is under development
- The Bridge Information System should be integrated so that the bridges can be viewed to see what cannot be safely attached. It should be possible to query the database to get information on the extent and type of guiderail and deck.
- 5 – 6 year plan to put on LAN
- Construction could use for claims situations and control of traffic plans
- Need rail height
- Cross slope info is helpful
- Crash data should be integrated
- Brad Smith is in charge of long range plan for GR
- Right of way should be included

3. Pavement Management

Interview dates: 6/2/98 and 6/9/98. Persons interviewed: Eduardo Block and Keith Hayden
Uses and comments:
- Started using in 1989 to evaluate distress
- Designers use to determine appropriate rehab strategies
- Used by Pavement Management to establish homogeneous sections
- Provides historic record to keep track of maintenance history
- Software is WISECRAX
- Designers use as measuring tool for shim coats
- Desirable enhancements:
  - Click at start and end to get length and quantity
  - Add pavement history and age
  - Add AADT, town number, maintenance district, pavement composition
  - GPR for network level PMS
  - Add FWD, skid list/texture

4. Incident Management

   Interview date: 6/2/98 and 6/9/98. Persons interviewed: David Cruz and Tom Iacobucci

   Uses and comments:

   - Primary use is in evaluating diversionary routes
   - Additional comments and desired features
     - Display TRUs
     - Zoom feature for TRU
     - Show time-space diagram using tag point
     - Present landmarks are random
     - Include (data on ?) signalized intersections
     - Increase vertical angle
     - "Fine tune" distance between frames
     - Mileposts are inconsistent with signal log and flat files

5. Rights of Way

   Interview date: 6/2/98 and 6/9/98. Person interviewed: John Durling

   Uses and comments:

   - Integrated with GIS (MGE)?
   - Inventory of excess land
   - In widening cases, appraisers can click on GIS and bring up window, thus avoiding field trips
   - Side view used for billboard study

6. Planning Inventory and Data

   Interview date: 12/15/98. Person interviewed: Eric Glover

   Uses and comments:

   - Uses 3 – 4 times per day
   - Primary use is to identify entrances in connection with major generators
   - Assist field crews in establishing locations for ATR counts
   - Video will be helpful in picking up features between frames
   - Need more thorough inventory of intersecting roadways

7. Maintenance

   Interview date: 6/2/98. Person interviewed: Joseph Misbach and Jeff Haggen.

   Uses and comments:

   - Establish pavement rating numbers
   - Determination of homogeneous pavement sections
   - Historic record of actions
   - Review pavement after complaints
   - Litigation, e.g., missing signs
   - Rail upgrading (with Michelle)
   - Two Maintenance Managers per district – one on LAN

- Need log kilometer accuracy improved in relation to log books maintained by Policy and Planning (could be off by as much as 0.1 mi.)
- Zoom feature for viewing pavement *was* good
- Loading/unloading discs is cumbersome
- What is logic of how routes are stored on discs?
- List what is on *both* sides of disc

7. Federal Highway Administration

Interview date: 6/2/98. Person interviewed: Robert Ramirez

Uses and comments:

- Big value in reducing field trips
- Certification inspection takes place at final voucher, which is well past physical completion
- Mass DPW asked for sign patterns on I-84. Were able to respond immediately
- Trucking industries
- Need to be able to drag to size window
- LAN would be very valuable, because could have immediate access

7.2 Central Surveys

Interview date: 6/2/97. Person interviewed: John Rinaldi

Uses and comments:

- Geodetic Section can see monuments and decide suitability as Global Positioning System (GPS) site.
- Improved location survey estimates for consultant work leads to better cost estimates
- Determination of drive time for traverse (where to pull off, etc.)
- Establish survey limits
- Determination of shoulder widths, side slopes, and roadway grades for survey traverse control lines
- Side views will be very helpful in checking abutting owners
- Side view of project sites to check improvements on private lands for property acquisition maps and location surveys
- Tie-in with GIS. Link AVI file from photolog
- Determination of project area characteristics such as development type (urban, residential, commercial, etc.), density, and topography

APPENDIX B

SUGGESTED SCREENS

Courtesy of David G. Bowers

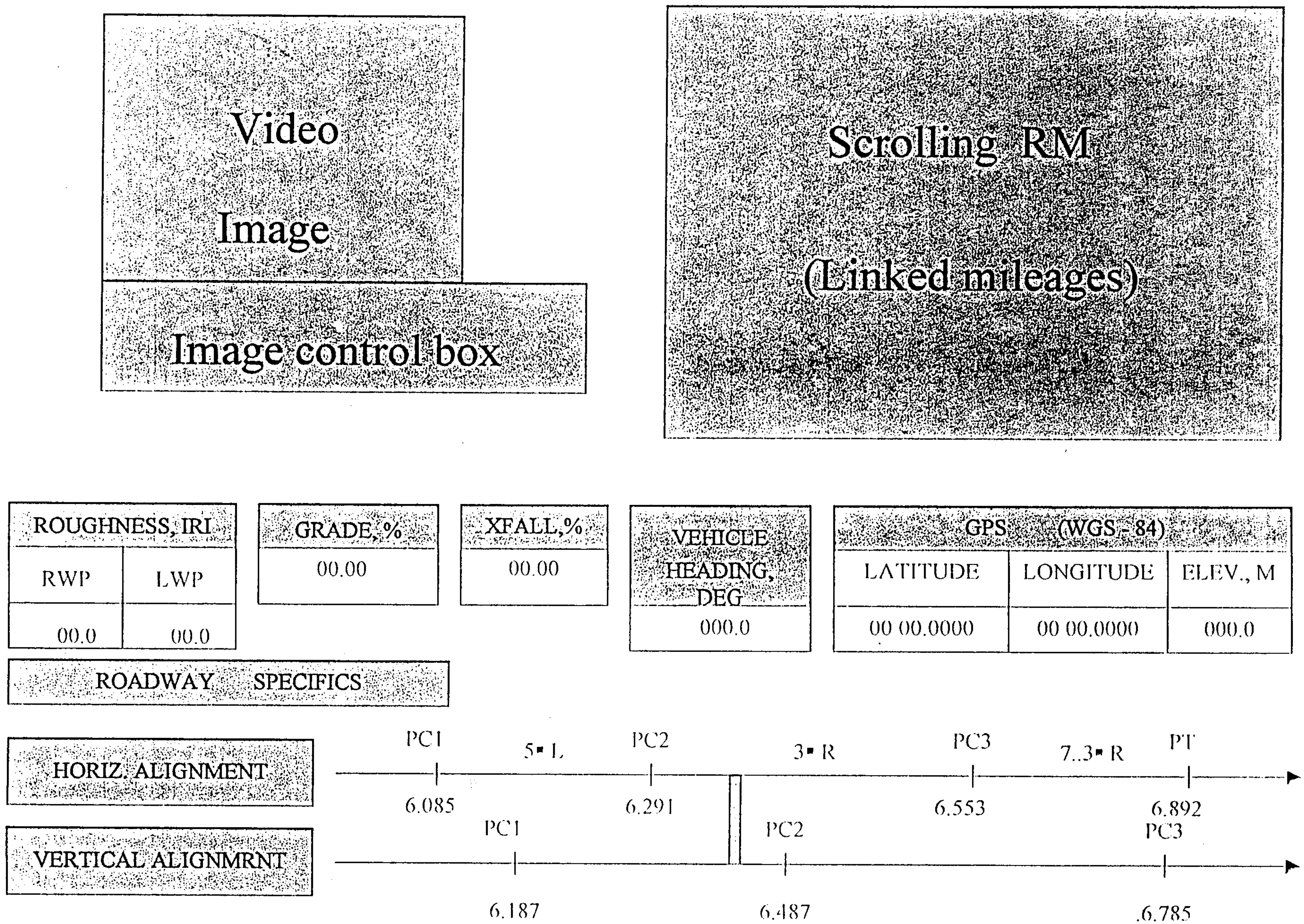


Figure B-1: Main Screen

EXPLANATION OF MAIN SCREEN

In addition to an image of the roadway ahead and a scrolling list of tie points (bridges, intersecting streets, etc.), this screen displays numerical information relative to the point on the roadway at which the image was captured. This information includes the following:

Roughness, IRI: The numerical data displayed under this item as IRI (International Roughness Index) are a measure of roughness-induced discomfort as sensed by a passenger in a standard car (mass, suspension) driven at a constant speed over the area in question. IRI values for both wheel paths (left and right) are reckoned in meters/kilometer of vertical displacement. This displacement represents the vertical movement that a passenger would experience over the current 10-meter section of road, multiplied by 100 for conversion to meters/kilometer. Double-click on the shaded "**Roughness, IRI**" box to display a menu devoted to additional roughness information presented in both numerical and graphical form.

- Detailed Explanation of IRI Measurement and Calculation
- Relational diagram

Grade, %: The single value displayed here with a "plus" or "minus" sign represents the longitudinal pitch of the road, which is defined as rise/run, i.e., the gain or loss in elevation over the horizontal distance traveled, expressed as a percent. A plus sign indicates an uphill slope in the direction of travel, and, conversely, a minus sign a downhill slope. (see relational diagram for the relative location of the actual grade measurement). Double-click on shaded "**Grade, %**" box to display a menu devoted to additional grade information in both numerical and graphic form.

- Detailed Explanation of Grade Measurement and Calculation
- Relational diagram

Cross Slope, %: The single value displayed here with a "plus" and "minus" sign represents the transverse slope (cross slope) of the lane being traversed. It is defined as the rise/run as measured from the left edge of the lane to the shoulder line, expressed in percent. Thus, a negative cross slope would indicate that the road surface pitches downward to the right. Conversely, a positive slope would indicate that the surface pitches transversally upward to the right. (see relation diagram for the relative location of the actual cross-slope measurement). Double-click on shaded "**Cross slope, %**" box to display a menu devoted to additional transverse-profile information in numerical and graphic form.

- Detailed Explanation of Cross-slope Measurement and Calculation
- Relational diagram

dealing with sections having a constant grade, or sections where the grade is continually changing in a vertical curve.

Box: Double-click on this box to display menu devoted to additional information on vertical alignment.

Detailed Explanation of Measurements and Calculations for Vertical Alignment

ROUGHNESS MENU

- **Individual IRI values**
  - Averaged over subsections within section of route
  - Averaged for section of route
  - Averaged for entire route
  - For section of route
  - For entire route

- **Graphics**
  - Histogram of individual values
    - Within section of route
    - For entire route
  - Plot of IRI versus station
    - Individual values (50-station max, one direction only)
    - Individual values averaged over subsections (maximum length = 50 x subsection length)

Click for specifics

Figure B-2a: Roughness Menu

ROUGHNESS MENU

SPECIFICS:

Direction: ● Log ● Reverse ● Both ● Average of both

Section: From Log Chainage 000.00 to 000.00 (type in kilometers)

From ARAN Chainage 000.00 to 000.00 (type in kilometers)

Subsection interval: 0.00 (type in interval desired from 0.02 to 10.00 kilometers)

Wheel Path: Left ● Right ● Both ● Average of both

● **Return to Main Menu**

Figure B-2b: Roughness Menu

ROUGHNESS

Individual IRI Averaged Over Subsections within Section

Rte. 183A   Section from ARAN Chainage 1.900 to 2.550   (IRI in m/km)

DIRECTION								
LOG				REVERSE				BOTH
Chainage (ARAN)	LWP	RWP	Avg.	Chainage (ARAN).	LWP	RWP	Avg.	Weighted Avg.
1.90-2.00	1.36/10	1.62/10	1.49	1.92-2.02	2.06/4	2.14/4	2.10	1.66
2.00-2.10	1.63/10	1.65/10	1.64	2.02-2.13	N.A./0	N.A./0	N.A.	1.64
2.10-2.20	↓	↓	↓	2.13-2.23	↓	↓	↓	↓
2.20-2.30				↓				
2.30-2.40								
2.40-2.50								
2.50-2.55	2.04/5	2.23/5	2.16	2.53-2.58	3.12/5	3.45/5	3.28	2..70
Avg.	1.58	1 .72	1.65	Avg	2.09	2.18	2.14	1.87
Act./Poss.	65/65	65/65			38/65	38/65		

Figure B-2c: Roughness

ROUGHNESS

Individual IRI Averaged Over Section

Rte. 183A — Section from ARAN Chainage 1.900 to 2.550 — (IRI in m/km)

	DIRECTION						
	LOG			REVERSE			BOTH
	LWP	RWP	WP Avg.	LWP	RWP	WP Avg.	Weighted Avg.
Avg. IRI	1.58	1.72	1.65	2.09	2.18	2.14	1.87
Actual/Possible	65/65	65/65		38/65	38/65		
Stand. Dev.	0.29	0.21		0.63	0.34		
Range High	3.37	3.19		4.68	3.85		
Low	0.84	1.15		1.02	1.21		

Figure B-2d: Roughness

ROUGHNESS

Individual IRI For Section

Rte. 183A Log Section from ARAN Chainage 1.900 to 2.550 (IRI in m/km)

Reverse Section from ARAN Chainage 1.895 to 2.550

DIRECTION								
LOG				REVERSE				BOTH
Chainage (ARAN)	LWP	RWP	WP Avg.	Chainage (ARAN).	LWP	RWP	WP Avg.	Avg.
1.90-1.91	2.85	3.06	2.95	1.92-1.93	1.95	1.85	1.90	2.43
1.91-1.92	3.62	1.54	2.08	1.93-1.94	2.06	2.03	2.05.	2.07
1.92-1.93	2.00	4.00	3.00	1.94-1.95	N/A	N/A	N/A	3.00
1.93-1.94 ↓	↓	↓	↓	1.95-1.96 ↓	↓	↓	↓	↓
2.54-2.55	1.32	1.76	1.54	2.53-2.58	2.38	3.06	2.68	2.04
Avg. IRI	1.58	1 .72	1.65	Avg IRI	2.09	2.18	2.14	1.87
Act./Poss.	65/65	65/65		Act./Poss.	38/65	38/65		
Std. Dev.	0.31	0.26		Std. Dev.	0.64	0.48		
Range: High	11.89	13.85		Range: High	15.01	8.48		
Low	0.72	1.24		Low	1.32	1.11		

Figure B-2e: Roughness

ROUGHNESS

Individual IRI Averaged Over Entire Route

Rte. 183A (IRI in m/km)

	DIRECTION						
	LOG			REVERSE			BOTH
	LWP	RWP	WP Avg.	LWP	RWP	WP Avg.	Weighted Avg.
Avg. IRI	1.75	2.09	1.92	1.81	2.35	2.08	1.99
Actual/Possible	586/610	586/610		490/612	490/612		1070/1222
Stand. Dev.	0.42	0.38		0.29	0.42		
Range High	9.81	5.69		11.35	7.24		11.35
Low	0.84	1.12		1.02	1.18		0.84

Figure B-2f: Roughness

ROUGHNESS

Plot of IRI Averaged Over Subsections

Rte. 183A   Section from ARAN Chainage 1.250 to 4.750   (IRI in m/km)

Direction: Log   Wheel Path : Left   Subsection Interval: 0.25 km

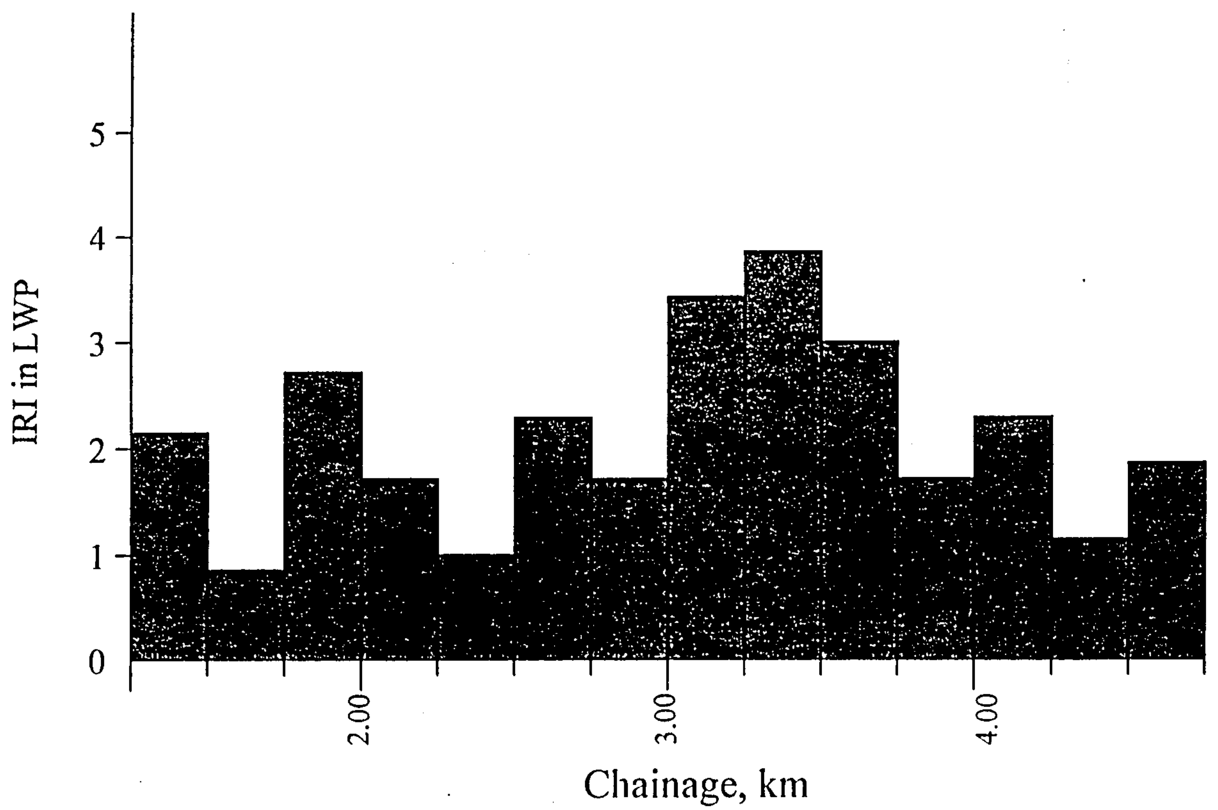


Figure B-2g: Roughness

ROUGHNESS

Histogram of Individual IRI Values

Rte. 183A   Log (Reverse) Section from ARAN Chainage 1.900 to 2.550

Direction: Log   Number of Readings: 138   Possible Number of Readings: 163

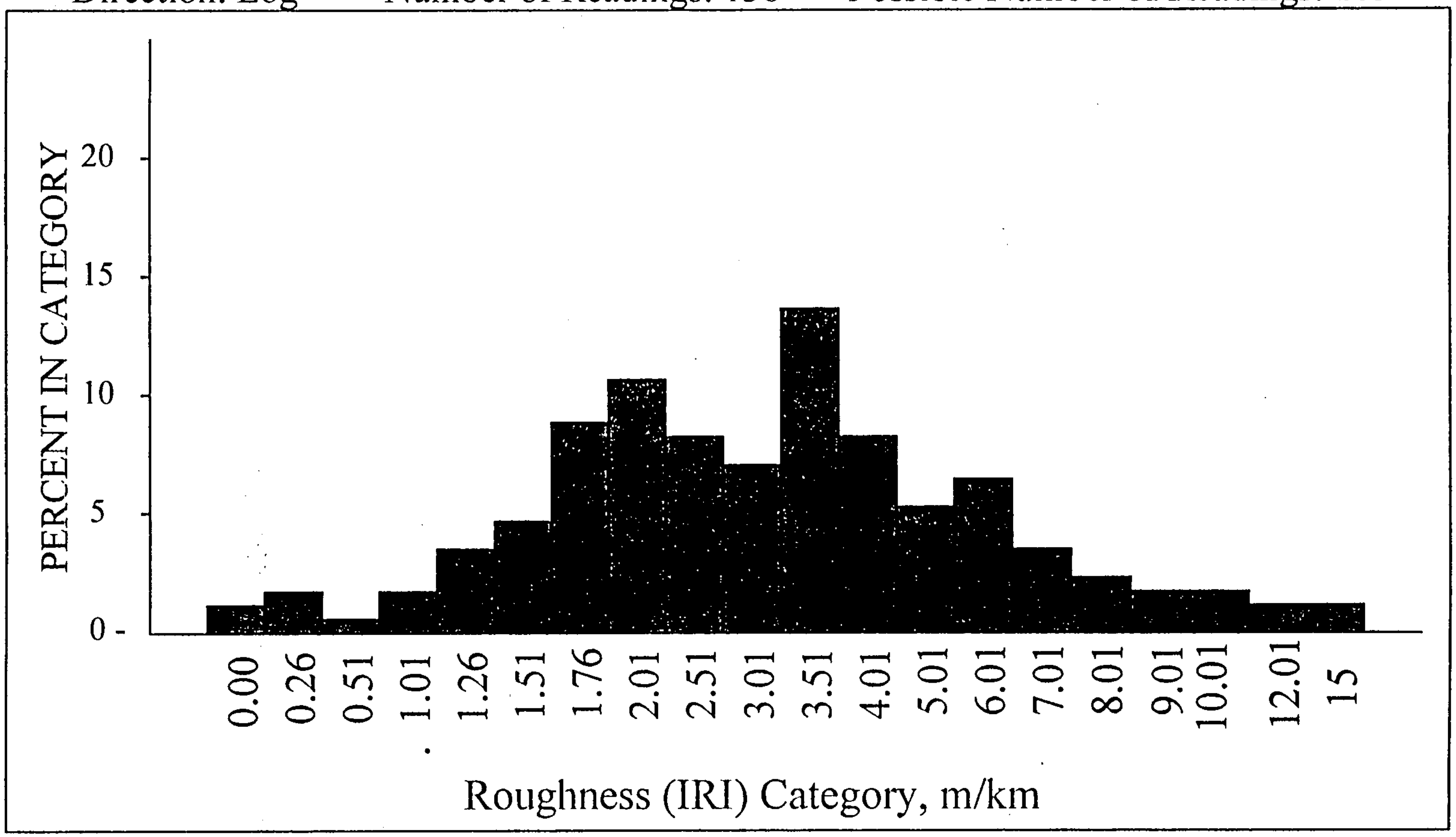


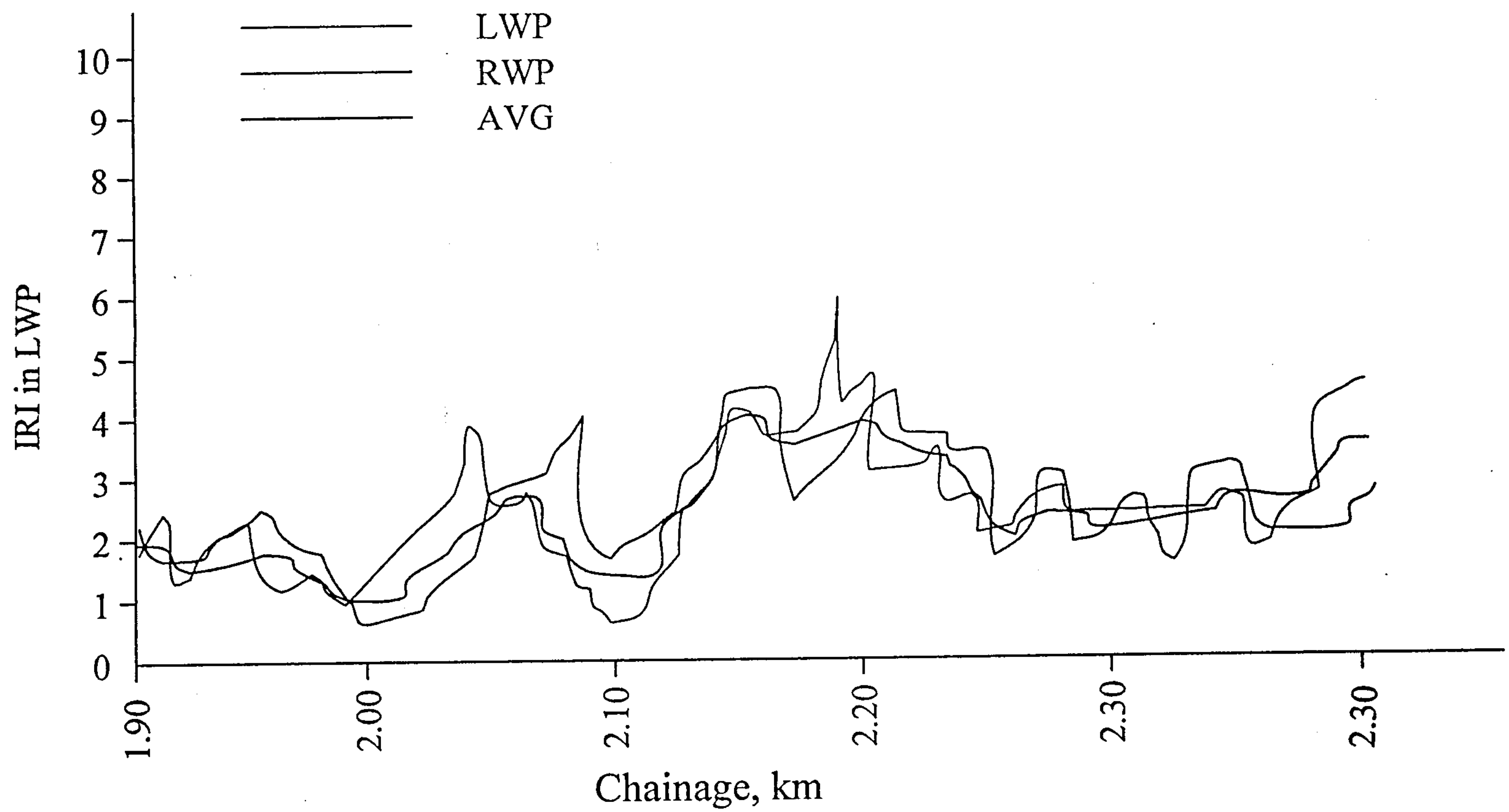
Figure B-2h: Roughness

ROUGHNESS

Plot of Individual IRI Versus Station

Rte. 183A Section from ARAN Chainage 1.90 to 2.40 (IRI in m/km)

Direction: Log



GRADE MENU

- **Individual Grade Values**
  - For section of route
  - For entire route
  - Averaged for section of route
  - Averaged for entire route
- **Graphics**
  - Histogram of individual values
    - Within section of route
    - For entire route
  - Plot of station elevations calculated from individual grade values

Specifics:

Direction : LOG REVERSE BOTH

Section: Log Direction: From ARAN Chainage 000.00 to 000.00 (type in)

Reverse Direction: From ARAN Chainage 000.00 to 000.00 (type in)

- **Return to Main Menu**

Figure B-3a: Grade Menu

GRADE

Individual Grade Values Over Section

Rte. 183A Log Section from ARAN Chainage 1.90 to 2.55
Reverse Section from ARAN Chainage 1.90 to 2.56

DIRECTION

LOG		REVERSE	
Chainage (ARAN)	Grade Value, %	Chainage (ARAN)	Grade Value, %
1.900	-0.1	1.900	0.1
1.902	-0.3	1.904	0.2
1.906	-0.4	1.908	0.3
1.910	-0.5	1.912	0.5
1.914	-0.6	1.916	0.7
1.918	-0.8	1.920	NA
1.922	-0.8	1.924	NA
↓			
2.546	9.8	2.552	-9.9
2.550	9.9	2.556	-9.8
		2.560	-10.0

Figure B-3b: Grade

GRADE

Individual Grade Values Averaged For

Rte. 183A   Log Section from ARAN Chainage 1.90 to 2.20
Reverse Section from ARAN Chainage 1.90 to 2.23

DIRECTION

LOG				REVERSE			
ARAN Chainage		Avg. Grade, %		ARAN Chainage		Avg. Grade, %	
From	To		N	From	To		N
1.90	2.20	+6.3	39	1.90	2234	-5.9	27

Figure B-3c: Grade

GRADE

Histogram of Individual Grade Values

Rte. 183A   Log (Reverse) Section from ARAN Chainage 1.900 to 2.550

Direction: Log   Number of Readings: 138   Possible Number of Readings: 163

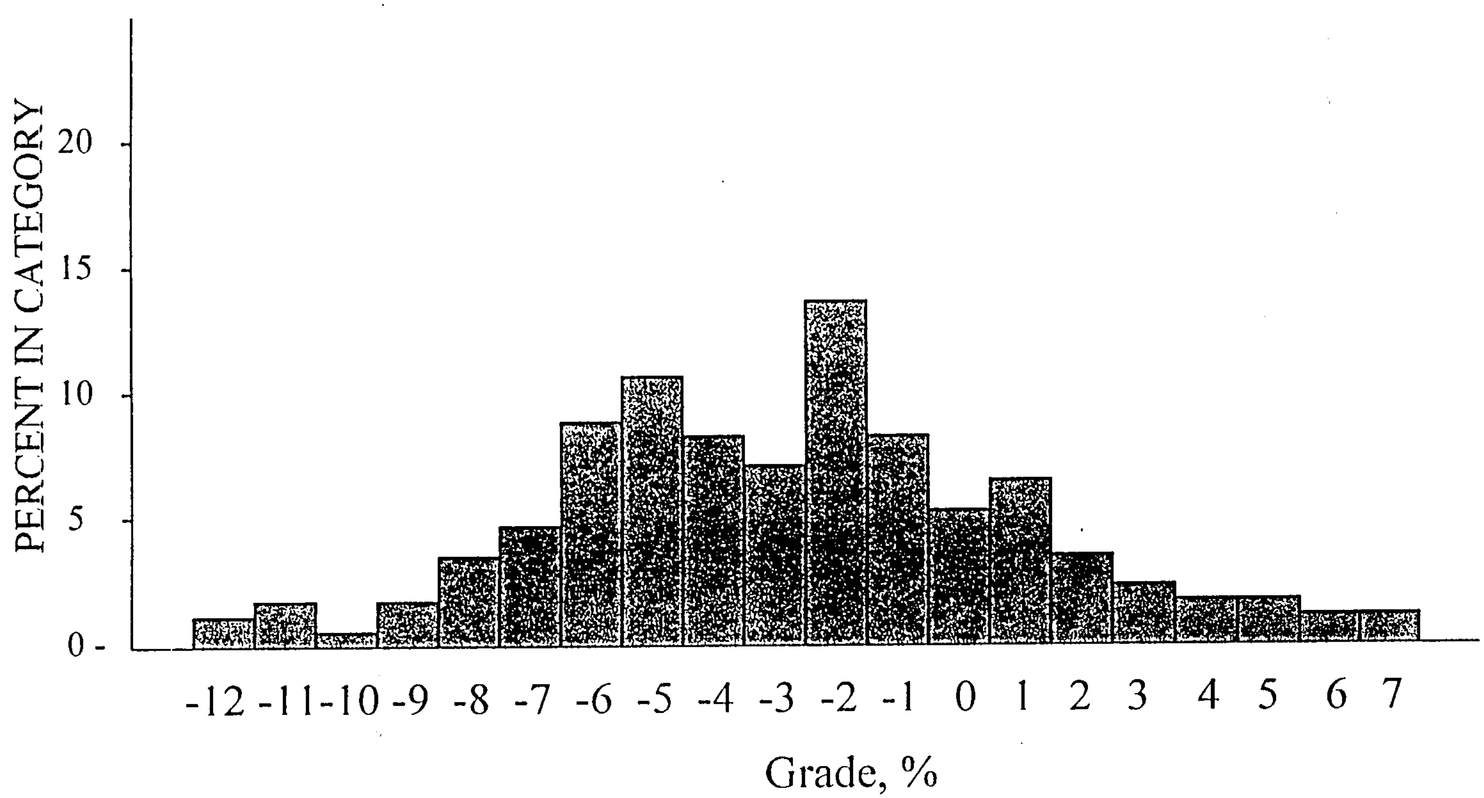


Figure B-3d: Grade

GRADE

Plot of Station Elevations Calculated from Individual Grade Values

Rte. 183A   Section from ARAN Chainage 1.900 to 2.550

Direction: Log   Number of Readings: 138   Possible Number of Readings: 163

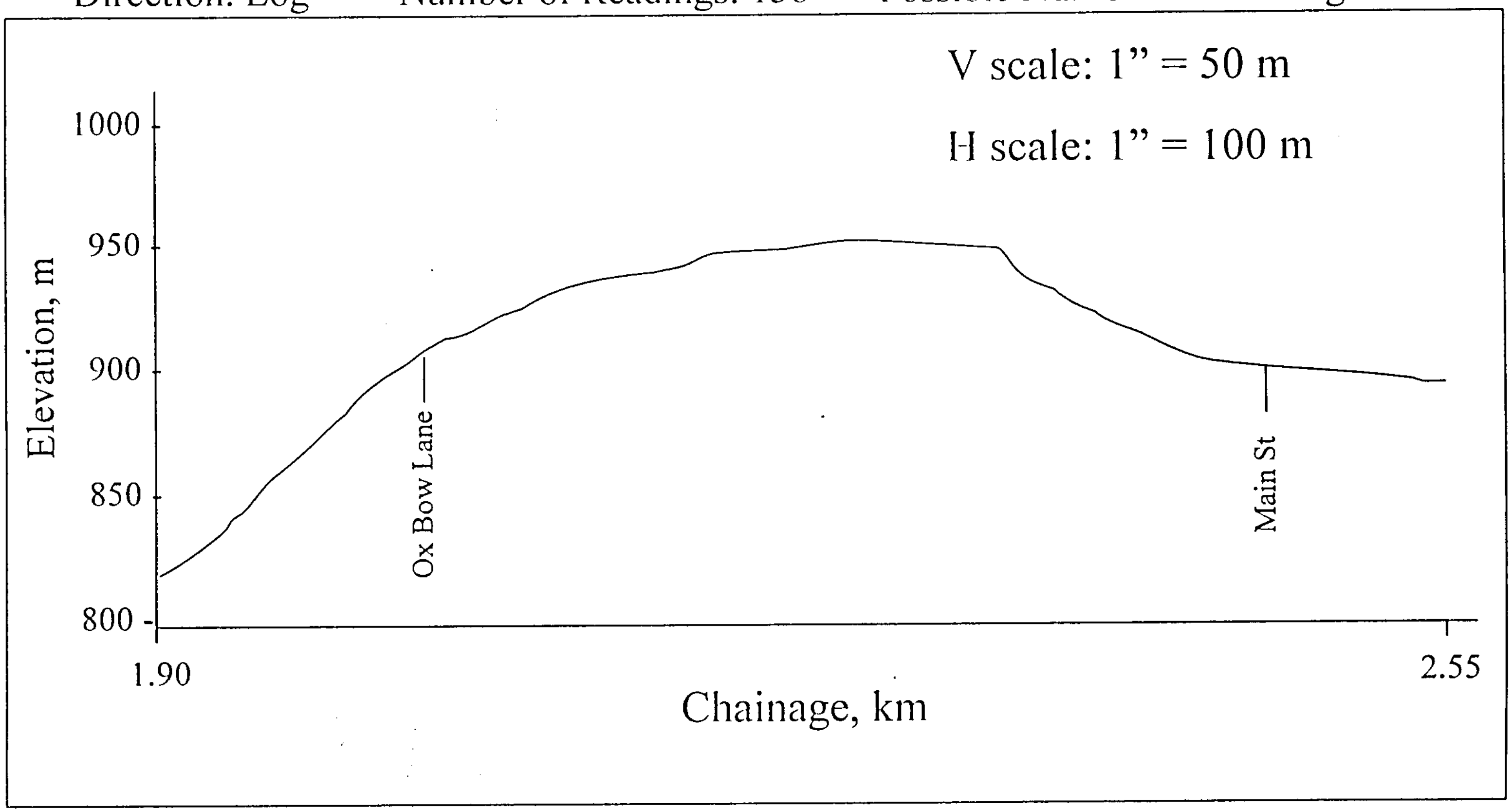


Figure B-3e: Grade

EXPLANATION OF GRADE:
ITS MEASUREMENT AND CALCULATION

Measurement: ConnDot's automated road analyzer (ARAN) is equipped with a military-grade gyroscope and four ultrasonic sensors located in each of the four corners of the vehicle chassis (see relational diagram). The gyroscope, which is rigidly affixed inside the front bumper, measures the pitch of the vehicle chassis with respect to its longitudinal axis. The four ultrasonic sensors or transducers measure the distance from each corner of the chassis to the surface of the road. They are calibrated against the surface of water standing in interconnected buckets placed beneath each of them. With the water in the buckets allowed to flow freely from one to the other, the level attained in one will be in the same horizontal plane as the levels in the others. Chassis pitch and sensor readings are taken every 4 meters of longitudinal travel by the ARAN.

Calculation: By averaging the readings of the two rear and two front sensors separately, and knowing the longitudinal distance between the two sets of sensors and the pitch of the chassis as determined by the gyroscope, the actual grade, or slope of the road between the two sets of sensors, is easily determined. The grade is listed as percent rise over run. Resolution is to the nearest tenth of a percent. Accuracy is to ± 0.05%. The diagram below shows the relationship between the foreground line of the image and the corresponding locations of the four-corner grade sensors and the resulting distance over which the grade is calculated.

XFALL MENU

- **Xfall and Rut Values**
  - Listed Individually
  - Averaged
- **Graphics**
  - Histogram of individual Xfall values
  - Histogram of individual rut values
    - For RWP ● For LWP ● Avg. Both WP
  - Plot of transverse profile at 5-meter stations

Specifics:

Direction : ● **LOG** ● **REVERSE** ● **BOTH**

- **Section: Log Direction: From ARAN Chainage 000.00 to 000.00 (type in)**
  Reverse Direction: From ARAN Chainage 000.00 to 000.00 (type in)
- **Entire route**

- **Return to Main Menu**

Figure B-4a: Xfall Menu

XFALL

Individual Xfall and Rut Depth Values

Rte. 183A   Log Section from ARAN Chainage 1.900 to 2.550

Reverse Section from ARAN Chainage 1.890 to 2.540

DIRECTION							
LOG				REVERSE			
Chainage (ARAN)	Xfall, %	Rut Depth, mm		Chainage (ARAN)	Xfall, %	Rut Depth, mm	
		LWP	RWP			LWP.	RWP
1.900	-4.0	4	3	1.890	-3.6	5	8
1.905	-4.8	6	1	1.895	-3.8	6	3
1.910	-5.0	8	2	1.988	-3.6	5	7
2.545	+3.2	11	13	2.535	+3.5	7	9
2.550	+3.6	12	14	2.540	+3.7	8	10
Avg.	-2.0	6	8	Avg.	-1.5	5	6
n possible	101	101	101	n possible	101	101	101
n valid	101	101	101	n valid	90	90	90
Max. +	6.8	15	19	Max. +	5.9	20	21
Max. -	-7.9			Max. -	-8.3		

Figure B-4b: Xfall

XFALL

Individual Xfall and Rut Depth Values Averaged For Section

Rte. 183A   Log Section from ARAN Chainage 1.900 to 2.550

Reverse Section from ARAN Chainage 1.890 to 2.540

DIRECTION							
LOG				REVERSE			
ARAN Chainage	Xfall,	Rut Depth, mm		ARAN Chainage	Xfall,	Rut Depth, mm	
1.900-2.550	%	LWP	RWP	1.890-2.540	%	LWP.	RWP
Avg.	-2.0	6	8	Avg.	-1.5	5	6
Max. Slope (+)	+6.8			Max. Slope (+)	+5.9		
Min. Slope (-)	-7.9			Min. Slope (-)	-8.3		
Max. Rut		15	19	Max. Rut		20	21
n possible	101	101	101	n possible	101	101	101
n valid	101	101	101	n valid	90	90	90

Figure B-4c: Xfall

XFALL

Histogram of Individual XFall Values

Rte. 183A   Log Section from ARAN Chainage 1.900 to 2.550

Direction: Log   Number of Readings: 131   Possible Number of Readings: 131

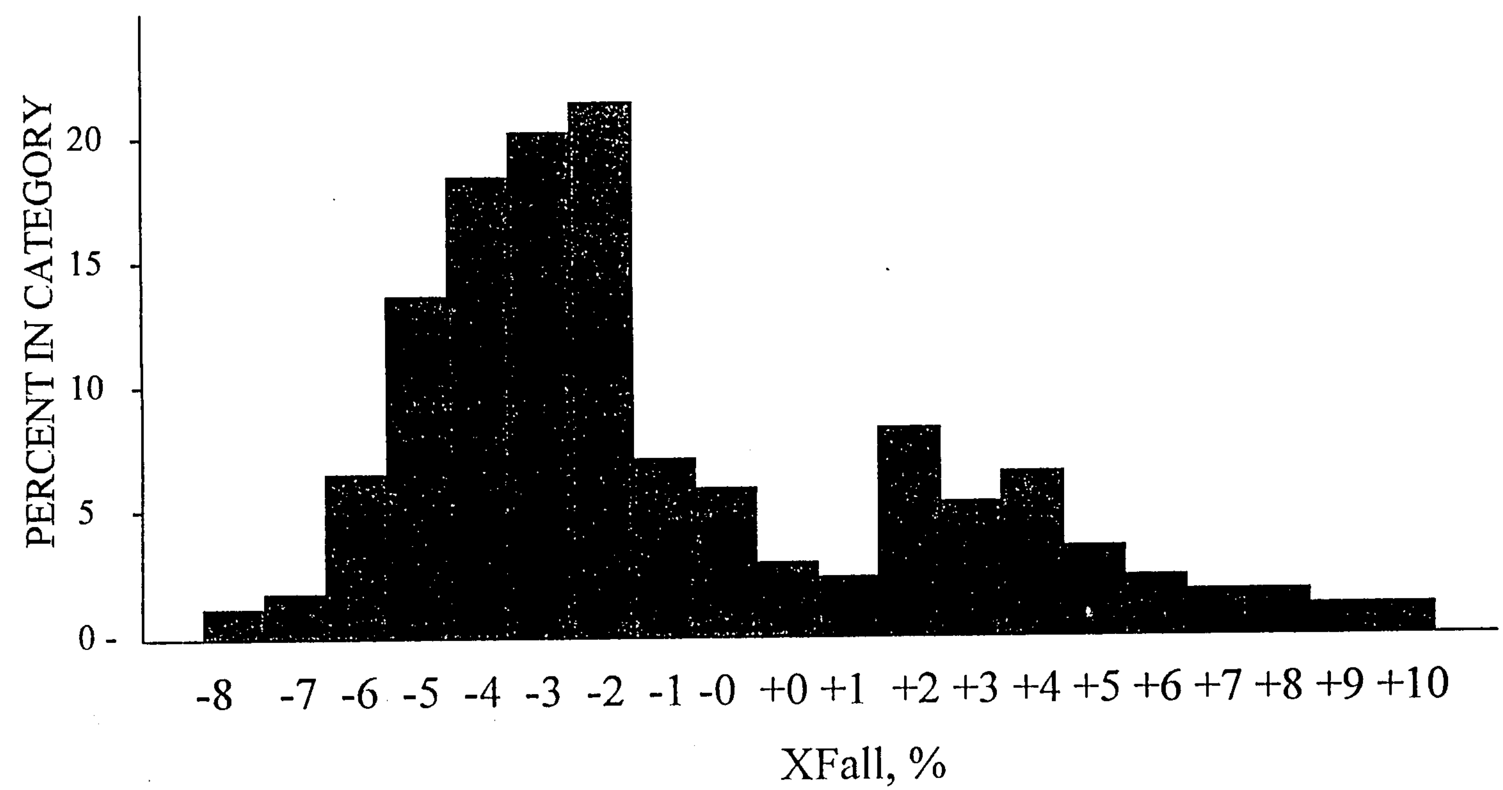


Figure B-4d: Xfall

XFALL

Transverse Profile

Rte. 183A   Log Section from ARAN Chainage 1.900 to 2.550   Direction: Log

ARAN Chainage 2.245.

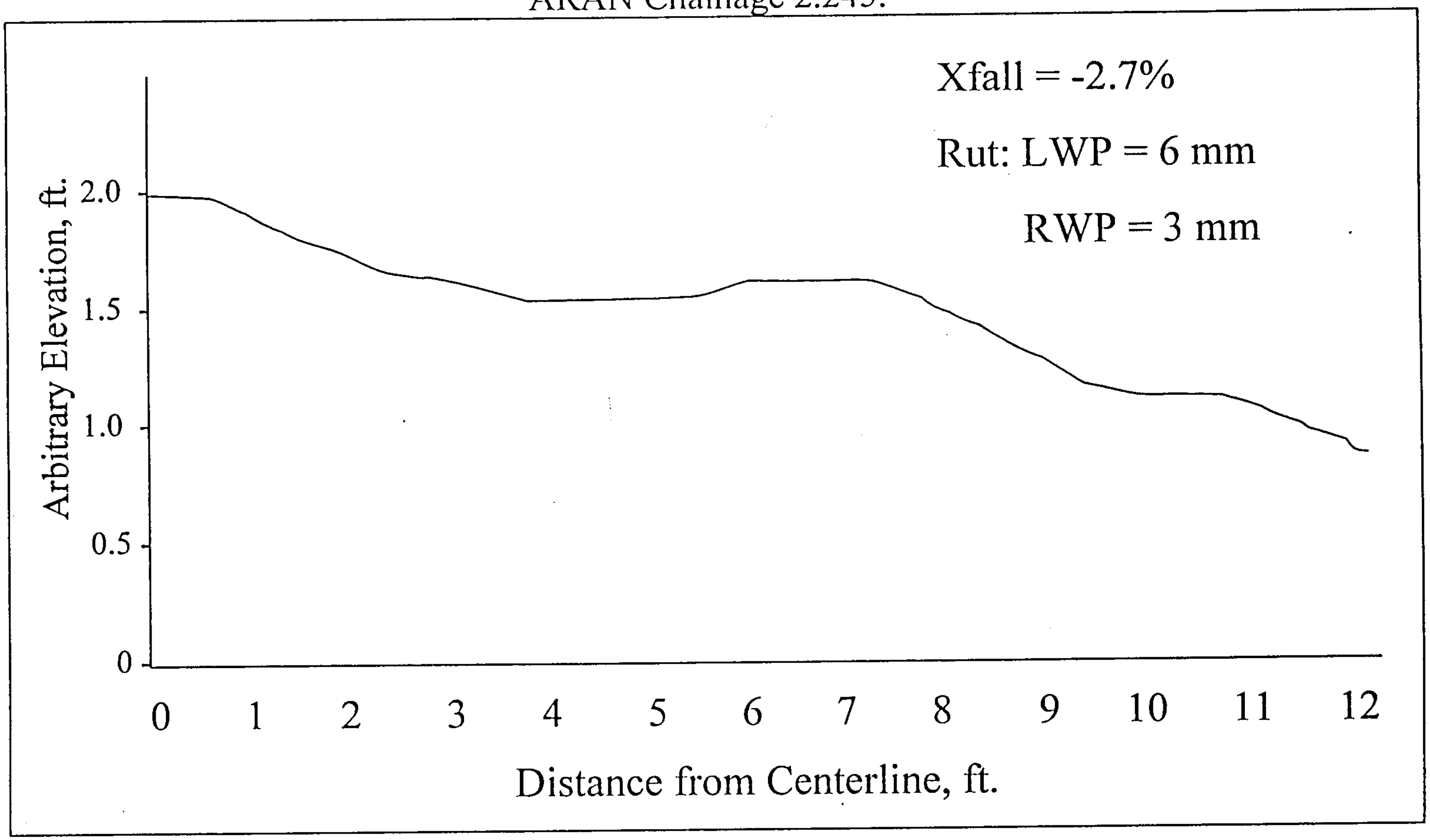


Figure B-4e: Xfall

EXPLANATION OF CROSS-SLOPE: ITS MEASUREMENT AND CALCULATION

Measurement: The front bumper or rut-bar housing (see relational diagram) of ConnDOT's automated road analyzer (ARAN) is equipped with a military-grade gyroscope and 37 ultrasonic transducers spaced 4 inches apart transversally along the bar. During annual network image and data acquisition, 25 of these sensors are normally deployed providing an 8-foot coverage of lanes that range from approximately 10.5 to 12 feet in width. Due to safety concerns, only 19 sensors providing 6-foot coverage are usually deployed when traversing roads where lane widths are less than 10.5 feet. With the telescoping arms fully extended, the full array of 37 sensors will provide a 12-foot coverage. Again, this deployment would be effected only at the project level where some means of traffic protection is afforded as a hedge against safety hazards. Each array of transducers, whether for the 6-, 8-, or 12-foot coverage, is calibrated separately over a level surface (body of water).

The transducers measure the distance from the bar to which they are affixed to the road surface. The even-number sensors are fired first, then the odd-numbered ones, and finally the even-numbered again. All this is accomplished in a matter of milliseconds. The two sets of distance measurements acquired from each of the even-numbered transducers are averaged, and are output together with the measurements of the single odd-numbered sensors, providing a reading in millimeters every 4 inches transversally across the lane. The gyroscope measures the roll of the vehicle about its longitudinal axis. Roll is output as percent rise over run in the transverse direction, and indicates the position of the chassis platform relative to the true horizontal plane at the location in question.

Calculation:

Transverse Profile - an accurate plot of the pavement surface in that portion of the lane subject to sensor coverage is obtained by combining the roll and individual sensor readings. For normal network data acquisition, the profile line for the two feet on each side of the rut bar (eight-foot lane coverage) would be extrapolated from the cross slope.

Cross Slope - given the profile points, the slope of the line connecting the points corresponding to first and last sensor readings is taken as the cross slope. This line is extended to the centerline and right edge of the lane. Because there is never full lane coverage at the network level, the accuracy of the cross slope will diminish with increasing curvature of the actual transverse profile of the road, and with decreasing percentage of lane coverage. The resultant cross slope is, however, a good reflection of the actual condition that exists in the lane at the point under consideration.

Rut Depth - given the distance from each sensor to the road surface, a search is performed for the point that yields the maximum positive slope between it and other points to the right.. Once this point is established, a line is extended back from the latter to the first point (line of maximum positive slope), and perpendiculars are dropped from this line to the intermediate points. The perpendicular with the maximum length is taken as the maximum rut depth for the left wheel path. The same procedure is employed to find the maximum rut depth for the right wheel path.

The diagrams below show the relationship between the sensors across the front bumper and the lane of travel, and the longitudinal relationship between the foreground line of the corresponding image and the point at which the transverse profile, rut depths, and cross slope were measured and/or calculated.

ARAN ATTITUDE MENU

- Individual Heading, Pitch, and Roll Values

Specifics:

Direction : LOG REVERSE BOTH

- Section: Log Direction: From ARAN Chainage 000.00 to 000.00 (type in)
  Reverse Direction: From ARAN Chainage 000.00 to 000.00 (type in)
- Entire route

- Return to Main Menu

Figure B-5a: Aran Attitude Menu

ARAN ATTITUDE

Individual Heading, Pitch, and Roll Values for ARAN

Rte. 183A Section from ARAN Chainage 1.900 to 2.550

DIRECTION							
CHAINAGE	LOG			CHAINAGE	REVERSE		
(ARAN)	HEADING	PITCH	ROLL	(ARAN)	HEADING	PITCH	ROLL
1.900	172.8	+3.6	-2.3				
1.904	172.9	+3.6	-2.3*				
1.908	172.7	+3.5	-2.4*				
1.912	173.8	+2.9	-3.6*				
1.916	174.9	+2.4	-4.7*				
1.920	175.7	+2.0	-4.5				
↓							
2.550	89.3	-4.0	+1.3				
Avg.	123.9	0.8	-2.2				
n possible	138	138	138				
n available	138	138	97				

* indicates that the value is interpolated.; heading is in degrees from true north; r and pitch are in %.

Figure B-5b: Aran Attitude

EXPLANATION OF HEADING MEASUREMENT

A military-grade gyroscope housed in the front bumper enclosure (see relational diagram) provides for measurement of the vehicle's yaw (about the z axis). The output is to the nearest tenth of a degree as measured clockwise from true north. Readings of 0.0, 90.0, 180.0, and 270.0 degrees would therefore indicate that the longitudinal axis of the vehicle, and not necessarily the road, is bearing to the north, east, south, and west, respectively. The reading gives a good indication of the roads bearing, but because of driver weave in the lane, may not reflect the exact bearing. When analyzed in sequence, the heading values are used to locate and calculate various characteristics of horizontal curves.

GEOGRAPHICAL POSITIONING MENU

- **Individual Latitude, Longitude, and Elevation Values**
  - WGS-84 coordinate system
  - Connecticut planar coordinate system

- **Graphics**
  - Mapping of Roadway (X-Y)
    - In WGS-84 coordinates
    - In Connecticut planar coordinates
  - Plot of longitudinal profile of roadway

    (DOT chainage versus elevation obtained from GPS.

Specifics: Direction ○ Log ○ Reverse ○ Both

- Section : Log ARAN chainage from 000.00 to 000.00

  Reverse ARAN chainage from 000.00 to 000.00
- Entire route

- **Return to Main Menu**

Figure B-6a: Geographical Positioning Menu

GEOGRAPHICAL POSITIONING

Individual Lat, Long, and Elevation Values (WGS-84)

Rte. 183A Section from ARAN Chainage: 1.90 to 2.55 (Log) 1.92-2.58 (Reverse)

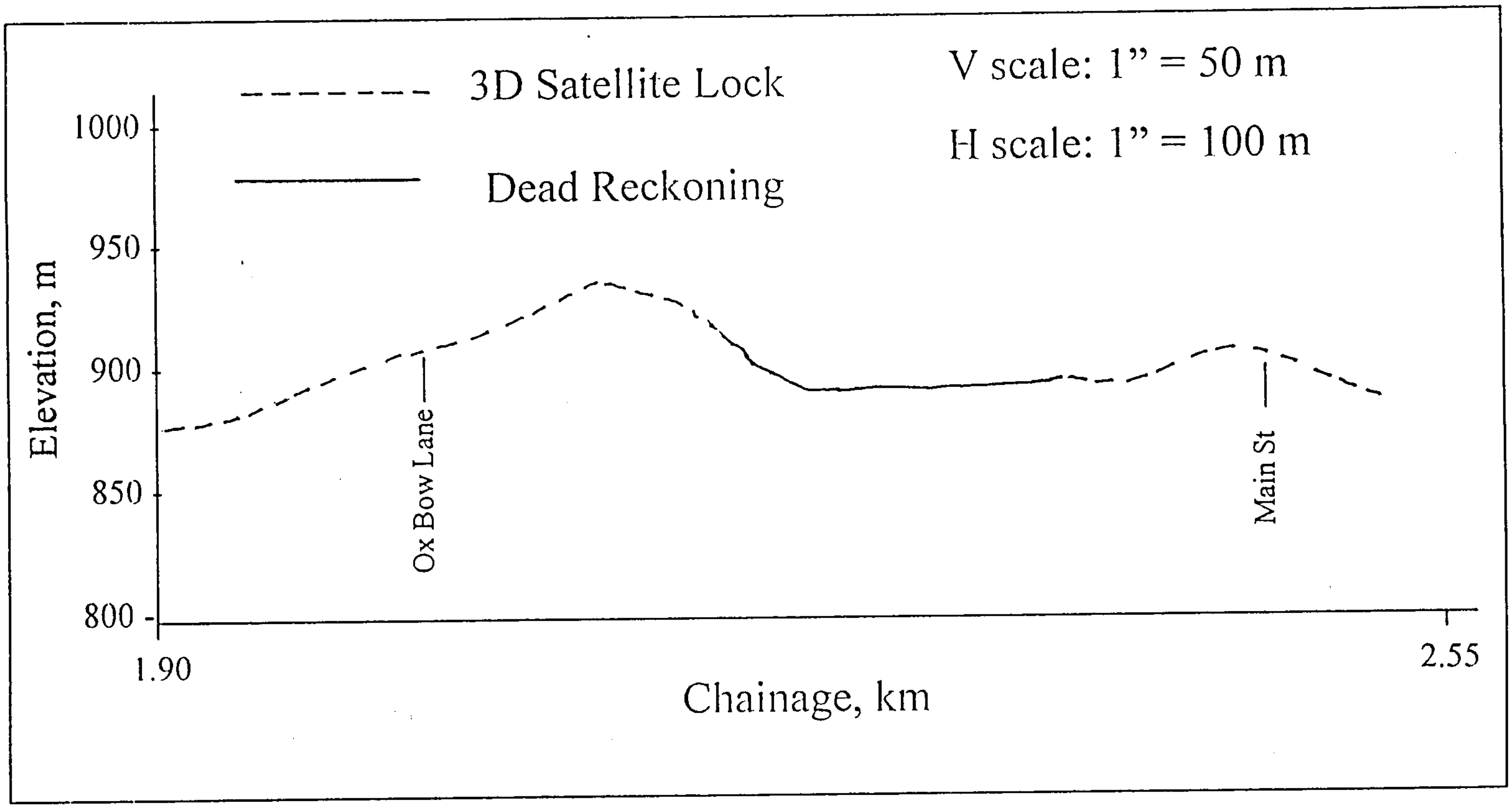
DIRECTION							
CHAINAGE (ARAN)	LOG			CHAINAGE (ARAN)	REVERSE		
	LATITUDE	LONGITUDE	ELEV.		LATITUDE	LONGITUDE	ELEV.
1.90	41 39.3872 N	72.15.0010 W	230.3	1.92	41 39.3875 N	72 15.0098 W	230.4
1.91	41 39.3863 N	72 14.9980 W	230.6	1.93	41 39.3866 N	72 14.9976 W	2308
1.92				1.94			
1.93				1.95			
↓				↓			
2.54	41 39.3284 N	72 14.1359W	181.2	2.56	41 39.3280 N	72 14.1363 W	181.9
2.55	41 39.3255 N	72 14.1312 W	179.6	2.57	41 39.3257 N	72 14.1318 W	179.3
				2.58	41 39.3214 N	72 13.1278 W	177.8

Figure B-6b: Geographical Positioning

GEOGRAPHICAL POSITIONING

Plot of Longitudinal Profile of Roadway Using GPS Station Elevations

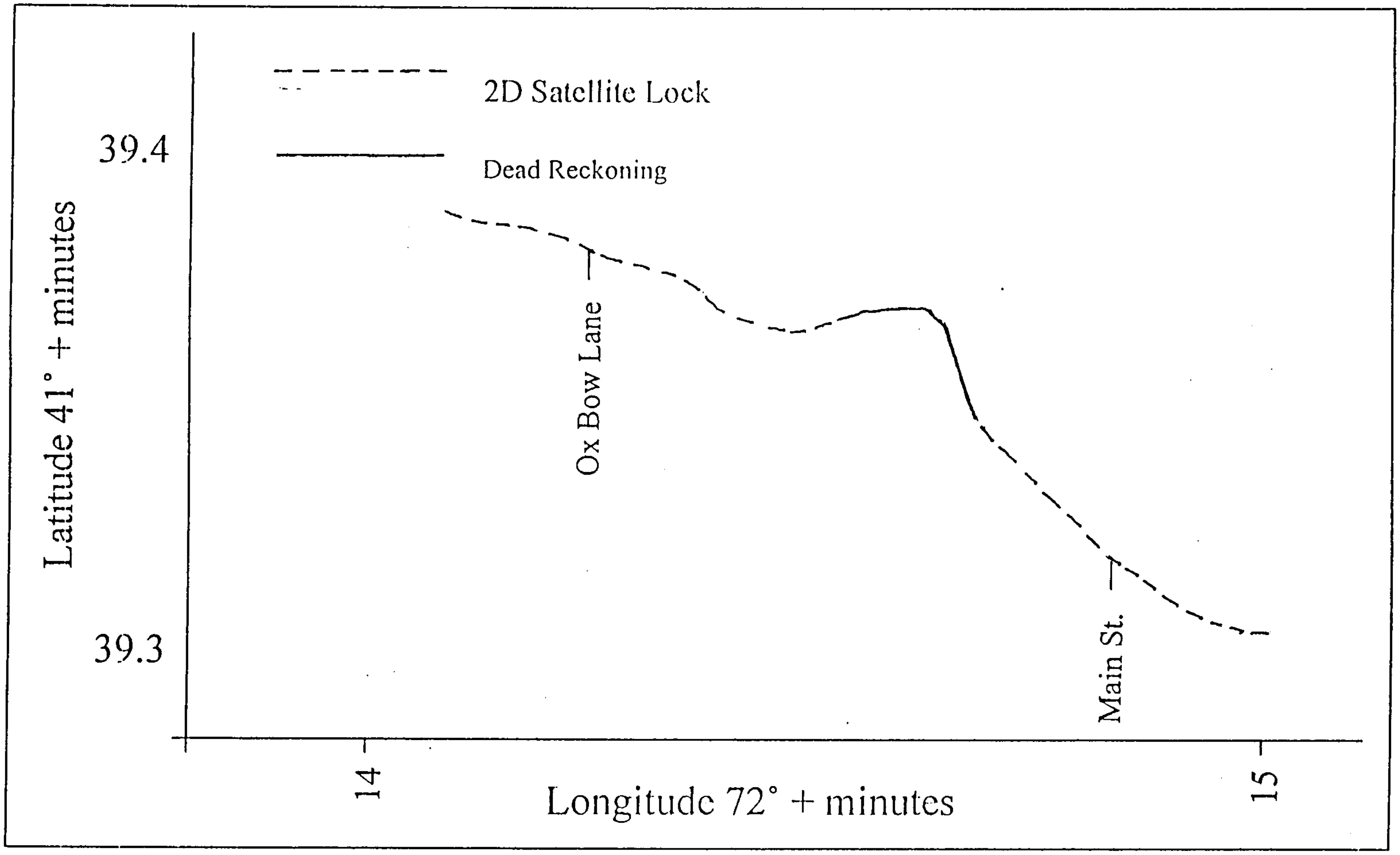
Rte. 183A   Direction: Log   Section from ARAN Chainage 1.900 to 2.550



GEOGRAPHICAL POSITIONING

Map of Roadway Plotted from GPS Coordinates

Rte. 183A Direction: Log Section from ARAN Chainage 1.900 to 2.550



EXPLANATION OF GLOBAL-POSITIONING: MEASUREMENT AND CALCULATION

Measurement: ConnDOT's automated road analyzer (ARAN) is equipped with a 12-channel GPS receiver (see relational diagram) capable of locking onto and receiving position information from up to 12 Navstar satellites simultaneously. This information, which is used for triangulating the position of the receiver, is downloaded into an office computer, where it is combined with similar information gathered from a base station with a known position (latitude, longitude, and elevation) in a routine called post-processing. This process makes it possible to overcome Department of Defense signal scrambling and achieve accuracies to ± 3 meters for latitude and longitude, and ±5 meters for elevation.

The receiver is programmed to poll the satellites every ½ second, regardless of whether the ARAN is stationary or moving, and independently of the ARAN's data- and image-acquisition schedule, i.e., not necessarily at the stations where images and data are acquired at regular distance intervals traveled (normally every 10 meters). Under normal conditions, at least 6 to 8 of the 22 Navstar satellites are visible and sufficiently high enough above the horizon to transmit acceptable signals to the receiver. The receiver must lock onto to at least four of these satellites to establish an accurate three-dimensional (x,y,z) fix on its location. When lock on only three satellites is achieved, accuracy is sufficient for only a two dimensional (x,y) fix. Occasionally, lock is obtained on less than three satellites due to underpasses, tunnels, heavy vegetative canopy, or tall structures adjacent to the roadway. When this happens, sufficient accuracy is lost even for a two-dimensional fix. This problem is resolved, however, by an algorithm that utilizes the output of the ARAN's gyroscopes and distance measuring instrument to "fill in" the coordinates of the stations where lock was lost on the required number of satellites, a procedure known as dead reckoning (see below).

Calculation: Satellite data from the receiver in the ARAN are downloaded to an office computer on which they are combined with base-station data to yield the coordinates of the receiver at the time that the signals were received. As indicated above, the number of coordinates obtained for the receiver's location from this post-processing will depend on the number of satellites successfully polled at the location in question (x, y, and z for four or more satellites, x and y for three satellites, and no coordinates for less than three satellites).

Thus, sets of satellite data are acquired by the receiver every one-half second, irrespective of vehicle speed, i.e., several sets of satellite data may be acquired over a 10-meter interval if the vehicle speed is sufficiently slow, or it is possible that no data would be acquired over this interval if the speed exceeds 10 m/sec. One algorithm executed during post-processing, searches for the data sets acquired nearest the 10-meter stations, and then determines the coordinates of the points at which these sets were acquired. Another algorithm utilizing information derived from the gyroscopes (grade and heading) and distance-measuring instrument (mileage or chainage) on-board the ARAN calculates the actual coordinates of the receiver's position, i.e., dead reckoning. As can be seen from the relational diagram below, the coordinates given would correspond to those of the receiver at the time that the forward-facing camera captured the image shown on the screen. This difference is about 7.53 meters (24.7 feet). Yet another algorithm calculates missing x, y, and/or z station coordinates (lock on an insufficient number of satellites) by means of interpolation and extrapolation of gyro and chainage data to the nearest stations where the coordinates were calculated directly from post-processing of sufficient satellite information. Processed in this manner, the data yield coordinates (x, y, z) for each 10-meter station sequentially along the route as traveled by the ARAN.

The accuracy of the coordinates determined directly from satellite data is within ± 3 meters in the x-y plane, and ± 5 meters in the z direction, as referenced from mean sea level. The greater the distance over which the coordinates are calculated via interpolation or extrapolation, however, the less accurate the result. Accuracy diminishes rapidly when dead reckoning extends much beyond 0.3 kilometer.

HORIZONTAL ALIGNMENT MENU

- **Listing of Individual Horizontal Curves**
  - For section of route
    - Log ARAN Chainage from 000.00 to 000.00
    - Reverse ARAN Chainage from 000.00 to 000.00
  - For Entire Route
    - Log
    - Reverse
- **Individual Horizontal Curve Analysis**
  - From above listing (click on desired curve)
  - From Main screen (increment videolog to desired curve and click on "Location" indicator under horizontal alignment
- **Return to Main Screen**

Figure B-7a: Horizontal Alignment Menu

HORIZONTAL ALIGNMENT

Listing of Individual Horizontal Curves

Rte. 183A Log Section from ARAN Chainage 1.900 to 2.550

Curve	Type*	Leg of Compound	PC, km	PT, km	Length, m	Degree	Direction	Radius, m
1	S	1/3	1.955	2.078	123	5.5	L	324
2	S	2/3	2.078	2.213	135	4.3	L	562
3	S	3/3	2.2.13	2.443	230	1.8	L	989
4	SP		2.460	2.693	233		R	0-1629

Note: Type of Curve (SP = Spiral S = Simple)

Figure B-7b: Horizontal Alignment

HORIZONTAL ALIGNMENT

Individual Horizontal Curve Analysis

Rte. 183A Direction: Log

Curve Type: Simple

Segment of Compound Curve: Yes Segment: 1 of 3

PC, km:	1.955	Maximum Xfall, %	+3.2%
Midpoint, km	2.017	Minimum Xfall, %	+1.4%
PT, km:	2.078	Avg. Xfall, %	+2.7%
Length, m	123	Rated Speed, mph	28
Direction:	Left	Speed Limit in Curve, mph	45
Degree of Curve:	5.5	Friction @ Speed Limit (SL)	.12
Radius, m	324	Friction @ SL + 5	.17
Grade at PC, %	-0.8	Friction @ SL + 10	.22
Grade at PT,%	+2.3	Friction @ SL + 15	.27
Avg. Grade ,%	+1.3%	Friction @ SL + 20	.36

Figure B-7c: Horizontal Alignment

HORIZONTAL ALIGNMENT:
ITS MEASUREMENT AND CALCULATION

Measurement: A military-grade gyroscope and distance-measuring instrument aboard the ConnDOT automated road analyzer (ARAN) output the heading and chainage information required to locate horizontal curves and determine their radii and length. The heading value (azimuth) is output to the nearest tenth of a degree, as measured clockwise from true north. A reading is taken and put to file every 4 meters of travel. It should be pointed out that the heading is actually the heading of the ARAN's longitudinal axis, and not necessarily the azimuth of the centerline of the lane at the station under consideration.

Calculation: Horizontal alignment of the roadway, or more specifically horizontal curvature, is calculated using sequential heading and chainage information. Three separate algorithms are used in this case.

Utilizing a filtering technique to eliminate driver weave, the first algorithm determines the existence of a curve and roughly locates its beginning (point of curvature, PC) and end (point of tangency, PT) based on cumulative chainage (mileage). The curve may be simple, compound, or spiral.

The second algorithm defines the PC and PT more precisely by analyzing the pattern of variation in the differences in heading from station to station. This procedure eliminates the influence of driver anticipation going into and coming out of curves.

Once the PC and PT are defined, the third algorithm analyzes the pattern of variation in the differences between successive heading values throughout the entire curve. This makes it possible to determine whether the entity exists as a single simple curve, is made up of two or more simple and/or spiral segments, or exists as a single spiral curve. This algorithm will also define the PCs of the internal segments of a compound curve. Knowing the station chainages, and the average change in heading throughout the curve or segments of the curve, the respective degrees of curve, radii, and lengths are readily calculated.

Note: The information resulting from the execution of these algorithms reflects the path traversed by the ARAN vehicle during network data and image acquisition, and does not necessarily reflect the path of the centerline or baseline of the roadway in question. The ARAN drivers are instructed to drive as closely as possible to the center of the outside or shoulder lane. Since the gyroscope is located approximately in the middle of the vehicle, the computed curvature will normally represent the path of the center of the outside lane. Occasionally, the ARAN will be forced to change lanes due to turns, lane drops, or lane additions. These movements will be recorded as short curves, and may or may not reflect the path of the center or base lines. In cases where the vehicle is forced to "go out of lane" for reasons such as obstructions to normal flow (maintenance operations, parked cars, pedestrians, etc.), the event is tagged and no curvature information will be supplied for that segment of road. In all cases, the user should view the images corresponding to the section of road under consideration to determine whether the ARAN had in fact deviated from the center of the intended lane. In the majority of cases (95% or better), the curvature information will be very close to information gleaned from plans in terms degree of curvature, radius, and length.

On many secondary roads that have never been formally designed and surveyed, a hodgepodge of horizontal curves exists. Many of these curves have spirals leading in and out, or even within a compound curve. Attempting to fit them to a simple curve would in many cases, be misleading. The algorithms classify these spirals as just that, "spirals." Their PCs and PTs, as well as their maximum degree of curvature are also determined.

VERTICAL ALIGNMENT MENU

- **Listing of Individual Vertical Curves**
  - For section of route
    - Log ARAN Chainage from 000.00 to 000.00
    - Reverse ARAN Chainage from 000.00 to 000.00
  - For Entire Route
    - Log
    - Reverse

- **Return to Main Menu**

Figure B-8a: Vertical Alignment Menu

VERTICAL ALIGNMENT

Listing of Individual Vertical Curves

Rte. 183A Reverse Section from ARAN Chainage 1.900 to 2.550

Curve	Leg of Compound	PC, km	PT, km	Length, m	Grade in, %	Grade out, %	Radius, m	Transition
1	1/3	1.955	2.078	123	+1.5	+2.6	60	Up/Up
2	2/3	2.078	2.213	135	+2.6	+4.8	93	Up/Up
3	3/3	2.2.13	2.443	230	+4.8	-2.3	203	Up/Down
4		2.460	2.693	233	-2.3	+3.9	185	Down/Up

Note: Length represents over the road distance.

Figure B-8b: Vertical Alignment

ROADWAY SPECIFICS MENU

Note: The information presented in the first two screens corresponds to the roadway only for the chainage shown on the monitor. The values and information for the various characteristics may or may not change with incrementing or decrementing chainage.

- **General Information**
- **Pavement Specifics**
- **Virtual Measurement Tools**
  - **Height of line segment above roadway**
  - **Height of object not on road**
  - **Distance of points from road line**
  - **Angle measurement**
  - **Distance along road line**
- **Return to Main Menu**

Figure B-9a: Roadway Specifics Menu

ROADWAY SPECIFICS

General Information

Rte. 183A Direction: Log ARAN Chainage: 2.080 (DOT Chainage:2.063)

Town: Colebrook	Roadway: Undivided
State System: Secondary	Roadway ADT: 2500
National Highway System: No	No. of Lanes: 2
Area: Rural	Lane Width: 10
Functional Class: Minor Collector	Shoulder Width: None
Access Control: None	Truck Lane: No
Maintenance District: 4	Truck Lane Width: NA
HPMS: Area: P	
Number: 007	

Figure B-9b: Roadway Specifics

ROADWAY SPECIFICS

Pavement Specifics

Rte. 183A   Direction: Log   ARAN Chainage: 2.080   (DOT Chainage:2.063)

Type: Composite

Last treatment: Mill 2 in. Bit. Conc. and Replace with 2 in. Class 1

Date: 9/20/95   **DOT Chainage:** 0.00 to 4.56

Previous treatment(s):

1) 1-1/2 in. Bit. Conc. (Class 1) from DOT chainage 1.23 to 4.56
(6/13/82) All Joints awed and sealed

2) 2 in. Bit. Conc. (Class 2) from DOT chainage 0.00 to 4.56
(8/01/73) All joints sawed and sealed

3) Original 8-in. reinforced concrete placed 7/2/40
DOT chainage from 0.00 to 6.89
25-ft weakened plane with expansion joints 100-ft on centers

Figure B-9c: Roadway Specifics