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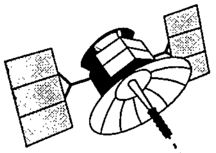

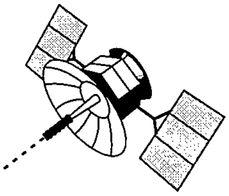

INVESTIGATION AND DEVELOPMENT OF A RESIDENCY-LEVEL GEOGRAPHIC INFORMATION SYSTEM TO SUPPORT PRIORITY APPLICATIONS

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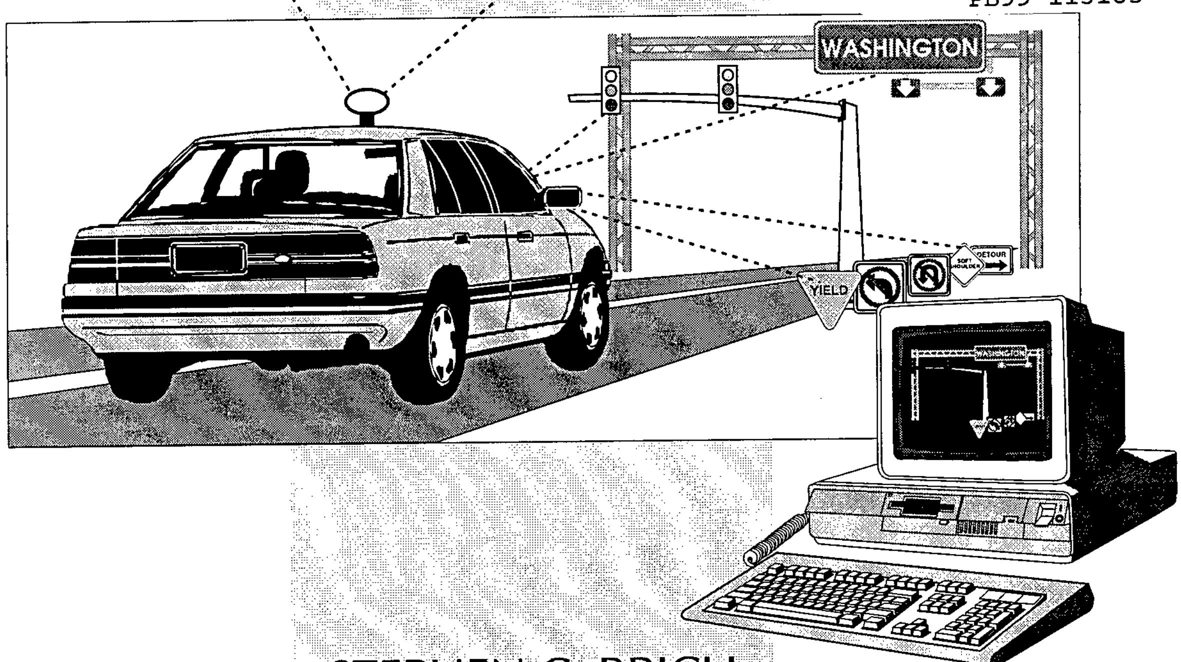

STEPHEN C. BRICH
Senior Research Scientist

G. MICHAEL FITCH
Senior Research Scientist

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VTRC
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16. Abstract

The primary responsibility of the Geographic Information Systems Lead Unit (GLU) of the Virginia Department of Transportation (VDOT) is to develop and implement the department's geographic information system (GIS). To fulfill this responsibility, the GLU developed a new GIS strategic plan that outlines six implementation strategies, one of which is the "Implementation of Priority GIS Applications." This strategy focuses on the operational requirements and the actions required to develop and maintain these applications.

In an attempt to serve as a catalyst in the development and implementation of priority applications at the residency level, research was undertaken to identify and develop a set of applications: guardrail inventory, sign inventory, drop inlet inventory, railroad-highway grade crossing inventory, and a mowing area calculation. These applications served as GIS examples intended to provide VDOT with a better understanding of the methods required to collect the spatial and attribute data when developing similar applications.

This report outlines the various methods used to collect the data and to define the associated accuracy requirements. The report also identifies the time expended in developing these applications. VDOT can use these methods to gauge the time required to develop similar applications on a statewide basis.

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Stephen C. Brich
Senior Research Scientist

G. Michael Fitch
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Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
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ABSTRACT

The primary responsibility of the Virginia Department of Transportation's (VDOT) Geographic Information Systems Lead Unit is to develop and implement the department's geographic information system (GIS). To fulfill this responsibility, the unit developed a new GIS strategic plan that outlines six implementation strategies, one of which is the "Implementation of Priority GIS Applications." This strategy focuses on the operational requirements and actions required to develop and maintain these applications.

To serve as a catalyst in the development and implementation of priority applications at the VDOT residency level, research was undertaken to identify and develop a set of applications: a guardrail inventory, sign inventory, drop inlet inventory, railroad-highway grade crossing inventory, and mowing area calculation. These applications served as GIS examples intended to provide VDOT with a better understanding of the methods required to collect the spatial and attribute data when similar applications are developed.

This report outlines the various methods used to collect the data and to define the associated accuracy requirements. The report also identifies the time expended in developing these applications. VDOT can use these methods to gauge the time required to develop similar applications on a statewide basis.

FINAL REPORT

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Stephen C. Brich
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INTRODUCTION

The primary responsibility of the Virginia Department of Transportation's (VDOT) Geographic Information Systems Lead Unit (GLU) is to develop and implement the department's geographic information system (GIS). In addition to determining the necessary computing, organizational, and staffing needs, the GLU is charged with identifying and developing GIS priority applications and facilitating their implementation. Priority applications are those applications that VDOT business units have agreed would be most helpful in carrying out VDOT's missions.

In early 1998, GLU developed a new GIS Strategic Plan to update the original plan published in October 1995.[1] This new plan outlines six strategies for implementing a well-coordinated and integrated GIS program:

1. Establish a proactive GIS institutional posture.

2. Establish a consistent, multiyear funding commitment.

3. Implement priority GIS applications.

4. Implement an ongoing educational program.

5. Integrate existing systems with emerging technologies.

6. Support the implementation of *Virginia Connections* and the MIS 2000 Strategic Plan.[2]

Strategies 1, 2, 4, and 6 address the larger institutional actions that are required to implement this type of a technology on such a large scale. Strategies 3 and 5 are more specifically geared toward end-users of the system and how data will be collected to support the GIS. Strategy 3 focuses on how VDOT will develop and maintain the GIS. One of the goals of this strategy is to produce near-term data and user-support products.

A potential source of data that can be used to support the development of priority applications is the inventory and condition assessment system (ICAS), currently under development in VDOT's Maintenance Division. ICAS, a process and database, will serve as the information foundation of VDOT's integrated maintenance management system (IMMS). The ICAS will provide for the collection of a detailed inventory and condition assessment of VDOT's maintainable assets, such as signs, guardrails, culverts, pipes, drains, and other items.

ICAS will be inventorying a wealth of maintainable assets and providing VDOT with a vast number of attributes for each type of asset. If spatially referenced, this information could be of significant value to the initial development of the GIS priority applications. To date, however, the data collection methods required for the ICAS and the priority applications have not been developed. Therefore, a set of priority applications that meet the needs of the GIS Strategic Plan needs to be identified and the functionality of ICAS through the development of proposed data collection methods needs to be demonstrated.

PURPOSE AND SCOPE

The primary purpose of this study was to identify and develop a set of priority applications and data collection methods that could serve as a catalyst for implementing a residency-level GIS. Estimates of time and costs associated with the acquisition and development of each data set were also compiled.

The project was limited to the investigation of five priority applications: a guardrail inventory, sign inventory, drop inlet inventory, railroad-highway grade crossing inventory, and mowing area calculation method. Because of the volume of data needed for each application and the time needed to investigate alternate methods of data collection, the collection area was limited to the interstate and/or primary roadways in Albemarle County, Virginia.

METHODOLOGY AND RESULTS

Identification of Priority Application

To identify five priority applications for this research effort, the researchers reviewed VDOT's original GIS strategic plan and consulted with staff from VDOT's Maintenance and Traffic Engineering divisions, the GLU, the Culpeper District Traffic Engineering Division, and the Charlottesville and Fauquier residencies. In each case, a common set of themes was identified: each group stressed the need for accurate information and condition assessments of guardrails, signs, pipes and drains, and railroad-highway grade crossings and accurate calculation of mowing areas.

Data Collection Methodology

Collection and assembly of data in a format that is readily usable for a variety of purposes are critical elements in the development of GIS priority applications. A variety of data collection methods were investigated for each of the five applications identified for this study. Specific modes of data collection included the use of aerial photographs (Figure 1); hard copy maps, such as VDOT's graphic logs (Figure 2); global positioning system (GPS) receivers; and a laser range finder used independently and in conjunction with the GPS receivers. Data collection methods, including time comparisons between various techniques, are reported. Methods used to link attribute data collected in the field and from legacy databases are discussed.

The methods available to capture spatial and (in some cases) attribute data digitally were evaluated and compared based on one or more of the following criteria:

- time required to capture subject data
- data quality (i.e., accuracy)
- equipment needed
- expertise needed.

Figure 1. Aerial photograph of I-64 in Albemarle County

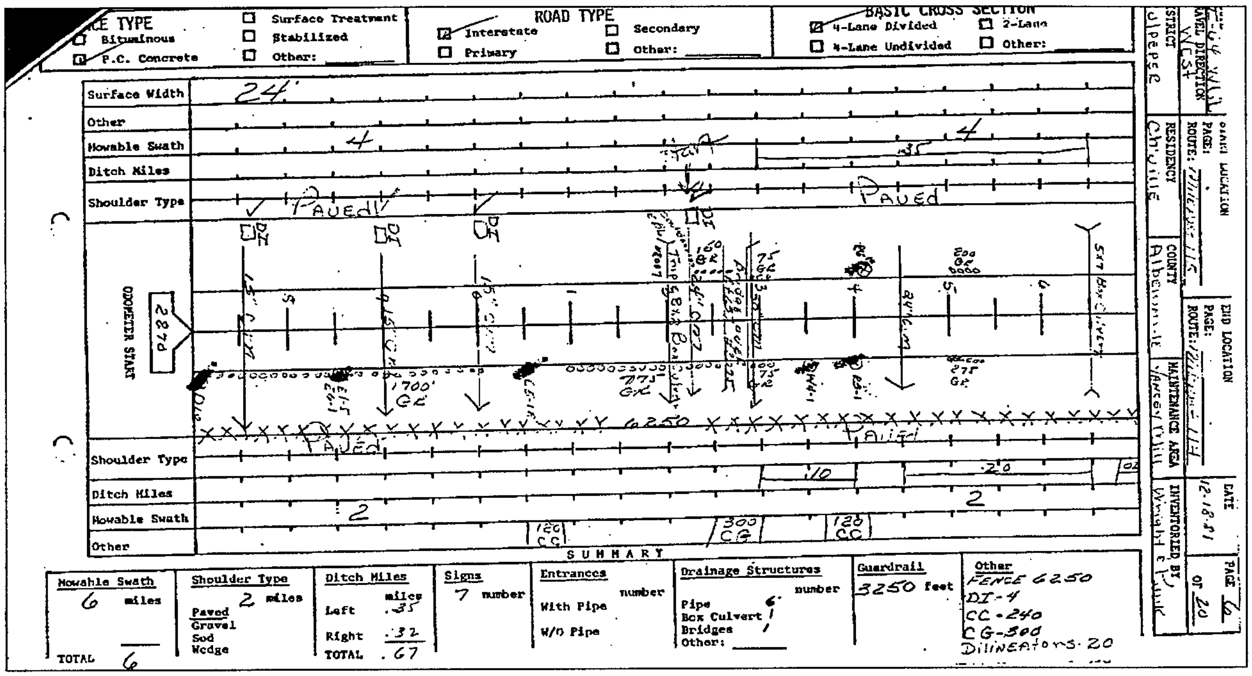

Figure 2. Graphic log of I-64 in Albemarle County

Once the data collection method was chosen (i.e., GPS), a subset of each of the five data sets was selected and captured to test the method. During this process, logistics related to the capture method were refined. Depending on the data set, this collection-change-collection process was repeated until the final method was developed.

The next step in the process consisted of collecting each data set in its entirety. The specific methods used, time required to collect and post-process the data, safety considerations, and any associated problems uncovered were all documented. Based on the analysis of these data, proposed methods for collecting similar data sets were developed.

Guardrail Inventory

The researchers investigated various methods to collect the guardrail feature, including using aerial photographs, graphic logs, and GPS. Guardrail features were not discernable from the aerial photographs obtained for the portion of I-64 in Albemarle County (30.5-cm [12-in] prints at a scale of 1:6000). The graphic logs obtained from the Charlottesville Residency did contain guardrail features, but it was impossible to pinpoint their physical location because of the method used to record them. In addition, the graphic logs contained no attribute data, such as guardrail height, material type, or type of end treatment. Therefore, the researchers decided that GPS would be used to collect both the spatial data (physical location) and the attribute data, including the feature's current condition.

Data Dictionary Development

After a review of the preliminary ICAS data requirements and consultations with the Culpeper District Traffic Engineer, the researchers developed a guardrail data dictionary they used to record multiple attributes for each guardrail feature. Appendix A contains the data dictionary and the associated attributes. The ICAS requirements proved to be a positive starting point, but for the information to be useful to the district staff, it had to be more detailed. Figure 3 depicts the makeup of ICAS and district requirements.

District Requirements	ICAS Requirements	
		Condition
		Condition Date
		Location (Latitude/Longitude) (Start/Stop)
		Direction of Travel
		Associated Route Number
		Associated Route Name
		Left or Right of Centerline
		Install/Repair Date
		Length
		Material Type
		End Treatment
		Run-on End Treatment
		Running Section
		Run-off End Treatment
		Delineators
		Location of Delineators
		Height of Rail

Figure 3. Makeup of ICAS and district requirements

ICAS requirements call for the length and the start and stop latitude and longitude of a given guardrail. Both of these pieces of information were indirectly collected through the use of the GPS receiver. That is, the latitude and longitude of the feature were collected at 0.7-s intervals while the researchers traversed the feature and the length was automatically calculated based on the beginning, intermediate, and end latitude and longitude coordinates.

District staff stated that they needed to know the guardrail's run-on end treatment, running section, and run-off end treatment classifications. They also wanted to know whether there were delineators on particular sections of the guardrail and, if so, where they were located (e.g., top, center, both, or none). Another important piece of information was the height of the guardrail, measured from the bottom of the rail to the road surface. Having all of this additional information would allow the district staff to keep accurate records and to identify more easily any changes required as new federal guardrail regulations come into effect.

The researchers structured the data dictionary in a manner that facilitated the data recording process. They ran several test runs before determining the most efficient order of data collection. This order allowed the data collector to enter the feature's attributes in a systematic manner as the vehicle approached and traversed the guardrail.

Data Collection

Various techniques for using a GPS receiver to collect spatial data were investigated. To have the GPS receiver's antenna as close to the actual guardrail location as possible (since the antenna determines where the location is calculated), several types of extension arms were considered. Each proved too cumbersome, required significant alterations to the vehicle used for collection, and posed a potential safety hazard to the researchers and other motorists. The feasibility of walking the length of each guardrail section was also tested. Although the data obtained were exceptionally good, and although this may be the only method feasible for particular urban areas, the method was far too time-consuming given the extent of guardrail to be collected.

The researchers ultimately collected the guardrail spatial data by attaching the GPS antenna to a fixed position on the roof of a van. On the interstate, the van was driven parallel with the guardrail from the right side shoulder. Measurements were taken to determine the horizontal distance from the receiver antenna to the top of the guardrail. This distance was entered as an offset in the GPS receiver, thereby automatically moving the location calculation stored in the receiver. For guardrail features on the right shoulder, an offset to the right was used (1.0 m), and for those in the median, a left offset value was entered (10.7 m) (see Figure 4). Because two offsets were required, data were collected on the right side in one pass and on the left side in another.

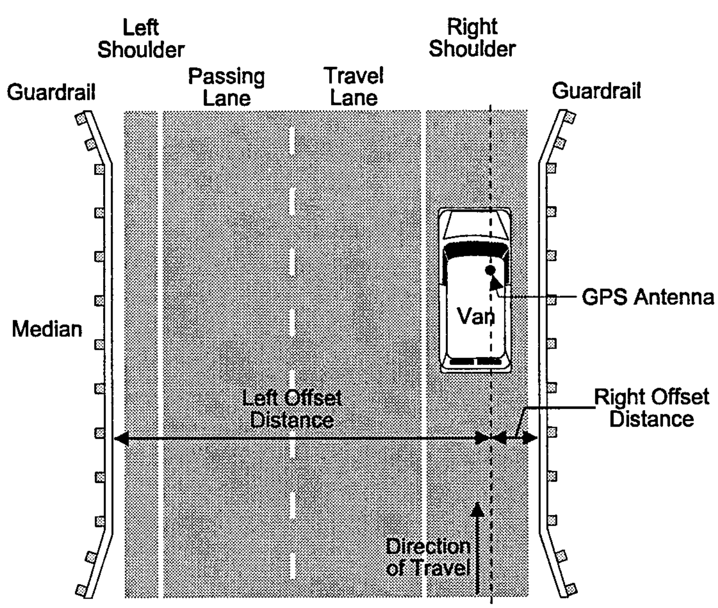

Figure 4. Guardrail offsets for interstate roadways

Data were collected on the primaries in a similar fashion, but because of varying shoulder widths and resulting safety considerations, all data were collected from the right travel lane. Again, measurements were taken to establish the offset distance by determining the horizontal distance from the antenna to the top of the guardrail. For guardrail data on divided primary roads, two offsets were used (see Figure 5): one for the guardrail on the right

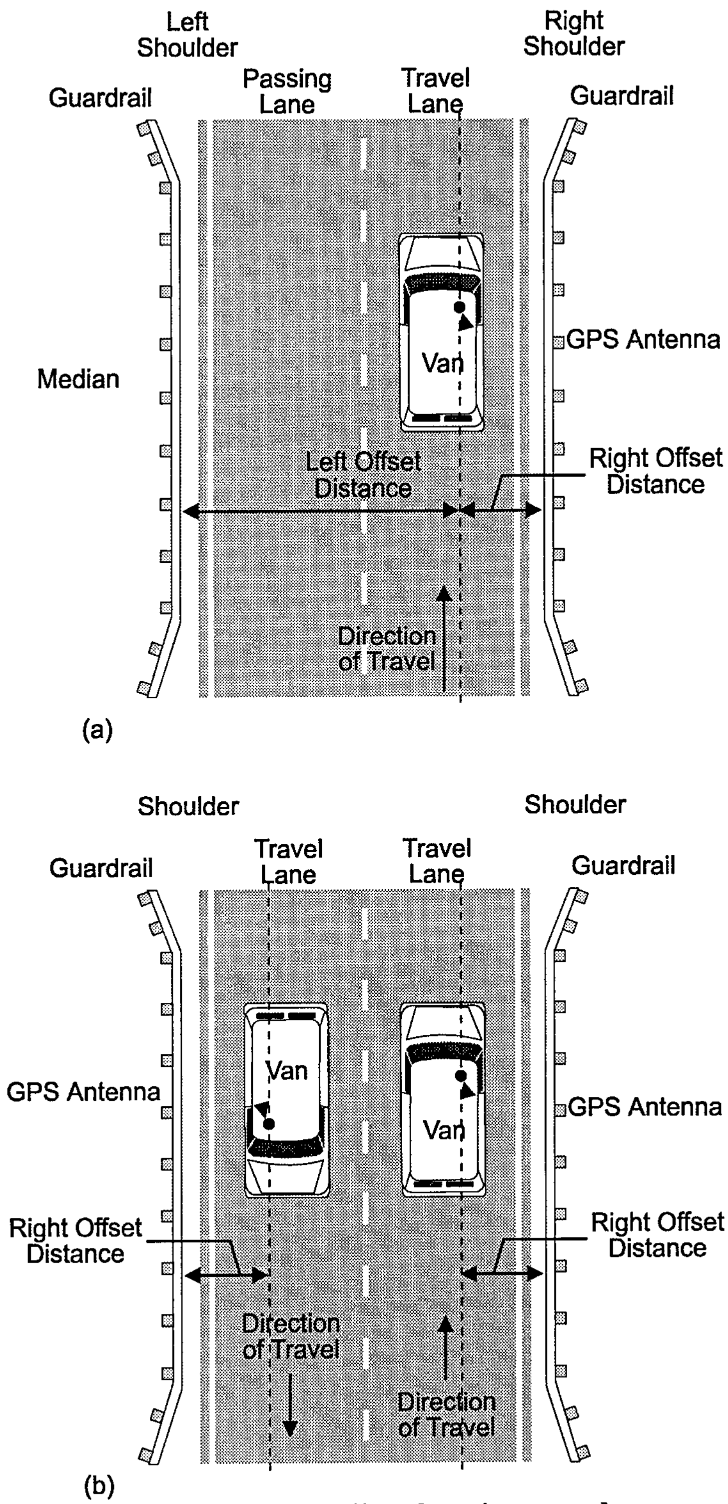

Figure 5. Guardrail offsets for primary roads

(1.2 m) and one for the guardrail section on the left (6.0 m) (see Figure 5A). In cases where the primary was undivided, only the right offset was required (see Figure 5B). Guardrail data collected for the primaries differed from that collected for the interstates because some sections deviated to follow a private drive or an intersecting roadway (see Figure 6). So that the collected spatial data properly represented what was found in the field, the van was driven parallel with the guardrail (i.e., followed the road or driveway) until the end of the feature was reached. The researchers felt it was important not only to capture the shape of the feature, but also to be able to calculate the length of the segment. The majority of the length of many of these features was off the roadway being inventoried.

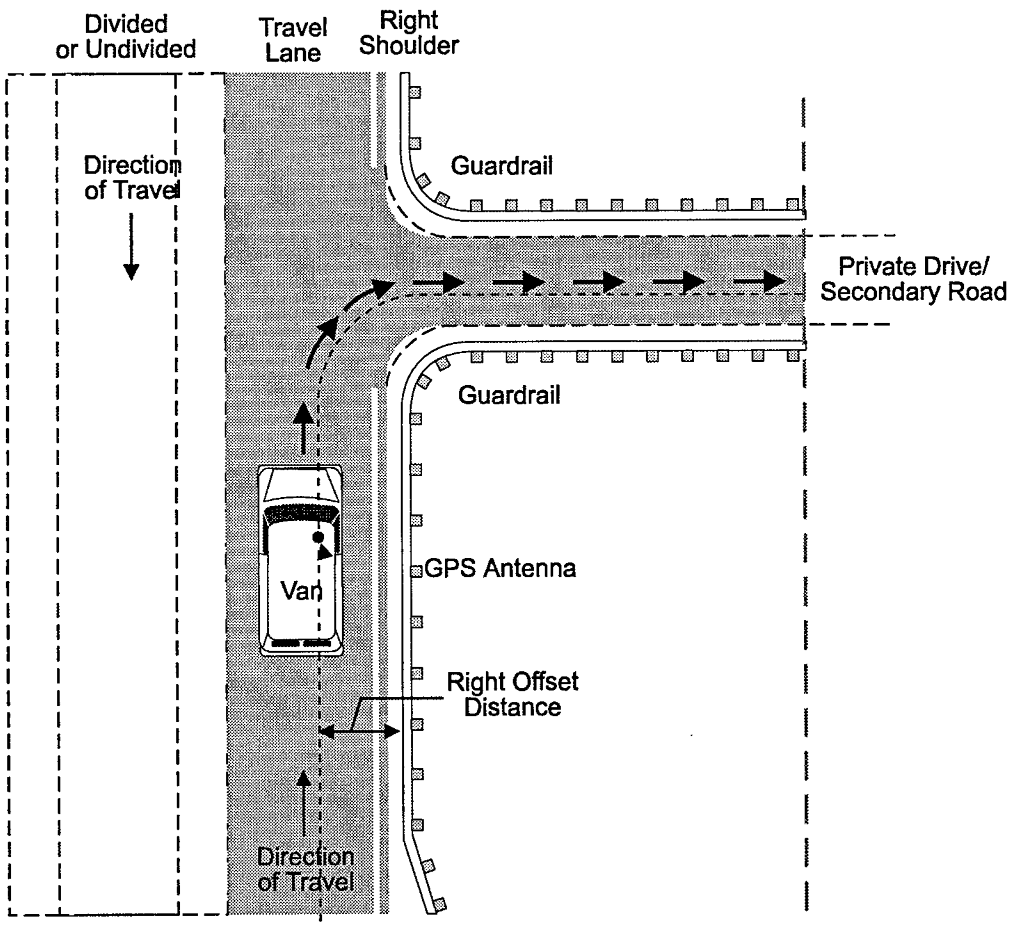

Figure 6. How private drives affect collection methods

Throughout the data collection process, the researchers noted that the distance from the shoulder or edge of pavement to the guardrail varied. However, given the range of error for the GPS receiver (0.5 to 2 m),[3] in the majority of cases, any deviations between the true offset and the value specified are usually within this error range.

Once all data were collected, they were downloaded to a personal computer, post-processed, viewed, and edited. These data were then exported to ARC/INFO and cleaned, and a coverage was created following the procedures previously outlined by Brich and Fitch.[4] The coverage was then transferred to ArcView for final display (see Figure 7).

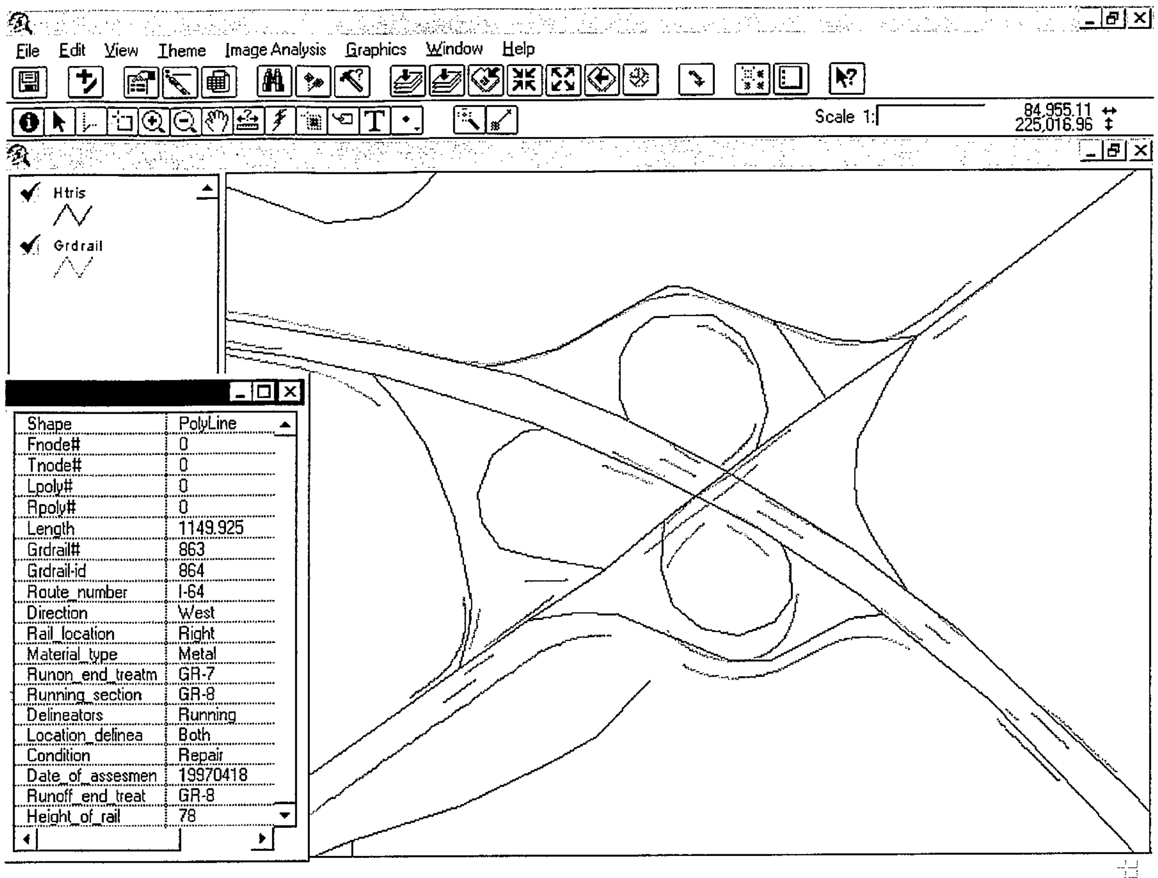

Figure 7. Guardrail application coverage

Guardrail Application Time and Effort

To collect the guardrail data set, the researchers drove 799.4 km (496.8 mi). Data on 1,008 guardrails, with a total length of 163.3 km (101.5 mi), were collected. Field collection time was 1,647 minutes, and post-processing and edit time was an additional 636 minutes. On average, it took less than 2 minutes to collect data for each guardrail section (see Table 1). Presented another way, it took just over 10.6 minutes per kilometer (17 minutes per mile) of guardrail to capture and process the data.

Table 1. Feature collection information

	Interstate	Primary	Total
Centerline (kilometers)	100.4	238.3	338.7
Distance Driven to Collect Data (km)	205.8	593.6	799.4
Number of Guardrail Features	348	660	1,008
Total Length of Features (km)	77.9	85.6	163.5
Collection Time (minutes)	701	946	1,647
Edit Time (minutes)	233	403	636
Average Length of Feature (km)	0.23	0.13	0.16
Number of Features/Kilometer of Centerline	3.47	2.77	2.98

Sign Inventory

The researchers explored several methods to collect a sign inventory for the section of I-64 in Albemarle County. These methods included the use of an existing hard copy sign inventory kept by the Culpeper District Traffic Engineer's office, graphic logs, GPS, and GPS with a laser range finder. The sign inventories kept by the district staff provided the researchers with each sign's legend and a mile referencing system for the eastbound and westbound directions. In some cases, the inventory provided sign letter heights or the installation date for a particular sign. The inventory did not contain any information about sign position (right mounted, left mounted, or overhead) or the *Manual on Uniform Traffic Control Device* (MUTCD) classification of sign type (i.e., stop sign, R1-1).[5]

The graphic logs obtained from the Charlottesville Residency did contain each sign's general location with respect to milepost and whether it was located on the left or right of the travel way. These logs also provided the MUTCD classification of the signs. However, it was not possible to identify the true accurate physical location of these features because of the method with which they were recorded. Also, neither the existing sign inventory nor the graphic log contained information on sign condition.

The researchers conducted a trial run to compare the existing inventory and the graphic logs with actual conditions. The researchers found that both were significantly out of date. Therefore, researchers decided to use a GPS integrated with a laser range finder to collect new spatial and attribute data. The researchers used the GPS receiver to collect the attribute information about the sign and the laser range finder to capture its location based on the location of the receiver's antenna. The range finder calculates the distance to the target and the direction (in degrees from north). It sends this information to the receiver by way of an RS-232 output. Thus, with the laser range finder, the researcher could stand on the right-hand shoulder and collect data on signs on the shoulder, in the center median, and overhead.

Data Dictionary Development

Using the same methodology as that employed to develop the guardrail inventory, the researchers created a data dictionary to be used in data collection. The researchers generated the dictionary after a review of preliminary ICAS data requirements and discussions with the Culpeper District Traffic Engineer. Appendix B contains the data dictionary and the associated attributes that were developed for this application. The data dictionary incorporated all ICAS requirements, except that MUTCD sign classification was used in place of sign names (names were added in a later step) and sign dimensions were not inventoried.

Collection Techniques

Various techniques of using the GPS receiver coupled with the laser range finder for the collection of spatial data were investigated. First, the researchers tried to capture sign information from inside the vehicle using the laser range finder; the GPS receiver antenna was affixed to the top of the van's roof. This scenario proved inaccurate since the magnetic field generated by the vehicle significantly altered the resulting bearing measured by the laser range finder. Next, the researchers attempted to stand just outside the vehicle with the laser range finder. This, too, proved to be of little use. The magnetic field of the vehicle was still too great, altering the bearing information. To overcome this limitation, an extension cord was manufactured to provide just the amount of distance required (1.0 to 1.5 m) between the van and the range finder to allow for accurate offset and bearing measurements to be made (see Figure 8).

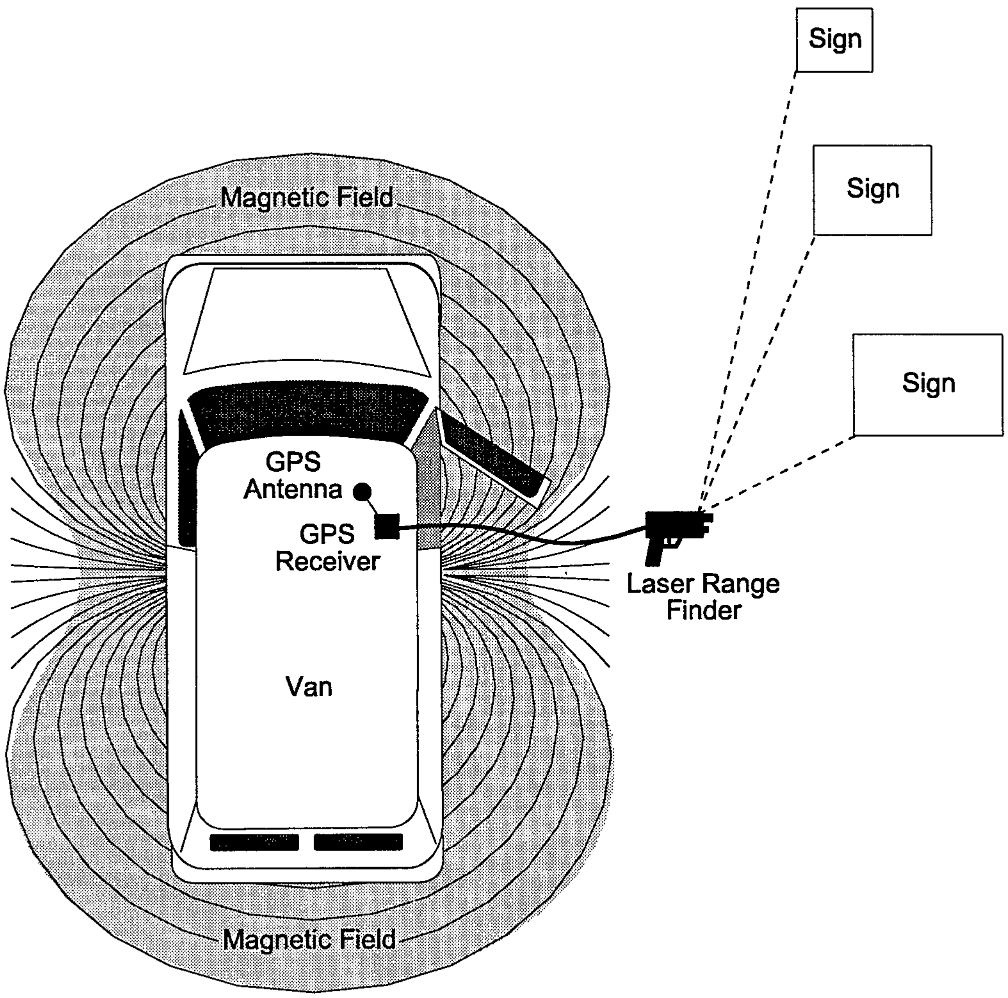

Figure 8. Vehicle's magnetic field

The researchers also tested the feasibility of capturing sign locations by walking to each sign with the GPS receiver. Although this technique yielded exceptionally good data, it was far too time-consuming given the number of signs to be inventoried and their varied locations within the right of way.

After evaluating the alternatives, the researchers selected the following method to collect the sign spatial data: they attached a GPS antenna to a fixed position on the roof of a van. The van was driven to within approximately 30 m (100 ft) of the sign to be collected and stopped on the right shoulder. The person in charge of data collection stood outside the van with the laser range finder outside the vehicle's magnetic field while the driver entered the sign's attributes. The laser range finder was then aimed at the sign face and triggered to capture a bearing and offset value. This method of collection allowed the researchers to remain on the right shoulder and collect all sign features regardless of where the features were mounted (left, right, or overhead). Only one pass was required to capture the sign features regardless of direction of travel.

Throughout the data collection process, it was noted that the distance from the vehicle and the laser range finder varied, which meant the location of the resulting offset varied. In the majority of cases, however, any deviation between the true offset and the value measured was usually within the error range of the GPS receiver (0.5 to 2.0 m).[3]

Once all data were collected, they were downloaded to a personal computer, post-processed, viewed, and cleaned. These data were then exported to ARC/INFO and cleaned, and a coverage was created following the procedures previously outlined by Brich and Fitch.[4] To record the sign names, the researchers developed a separate ASCII file that contained both the MUTCD classification of signs and the sign's respective name (i.e., R1-2, Yield sign). This file was related to the coverage's attribute file, thereby placing sign names next to the sign classification in the coverage attribute file. The coverage was then transferred to ArcView for final display (see Figure 9).

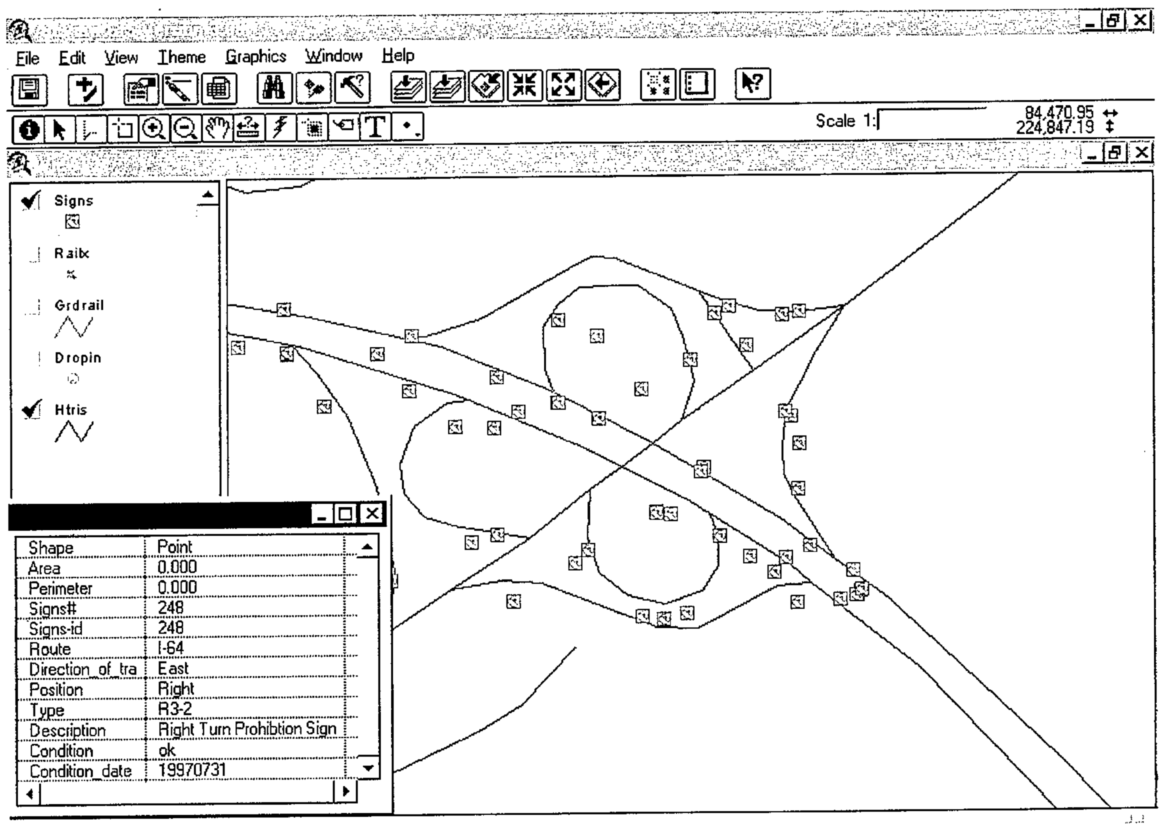

Figure 9. Sign application coverage

Sign Inventory Time and Effort

A total of 843 sign features were collected with a combined field collection, post processing, and editing time of 3,720 minutes. This averaged out to be approximately 4.4 minutes per feature. The researchers feel that this figure is inflated due to the inexperience of the field collection staff with the use of the GPS equipment and their unfamiliarity with the MUTCD classification of signs, as well as other logistical problems (i.e., computer problems). Data collection would probably become more efficient as field staff became more familiar with the equipment and the specifics of the features to be collected.

Drop Inlet Inventory

The researchers explored the use of aerial photographs, graphic logs, GPS, and GPS with a laser range finder to collect the I-64 drop inlet inventory. Most of the drop inlets were readily identifiable from aerial photographs (30.5-cm [12-in] prints at a scale of 1:6000). However, several drop inlets were located in the center median with heavy tree cover and/or debris that precluded them from being visible in the photographs. In addition, the researchers were unable to determine drop inlet condition and direction of flow from the photographs.

The graphic logs obtained from the Charlottesville Residency did, in most cases, contain drop inlet direction of flow, size and type of pipe, general location with respect to milepost, and whether the drop inlet was on the left or right of the travel way. However, in a number of cases, the graphic logs were inaccurate.

The researchers also used a GPS receiver integrated with a laser range finder. This approach allowed for remote collection of the data, thereby reducing data collection time, but precluded the researchers from assessing the condition of the inlet and its direction of flow. Therefore, the researchers opted to use a GPS receiver alone to collect spatial (location of the drop inlets) and attribute (current condition) data.

Data Dictionary Development

Using the same approach described for the other applications, the researchers developed a data dictionary to enable them to collect multiple attributes for each drop inlet feature in the GPS receiver. Appendix C contains the data dictionary and the associated attributes that were developed for this application. The ICAS requirements provided a fair starting point. In addition to the ICAS requirements, the researchers recorded the type of drop inlet, its flow direction, and the pipe material leading from it.

Data Collection

The researchers collected spatial data by walking to each drop inlet with the GPS receiver and antenna and entering attributes while standing on top of the inlet's grate. This same process was used for each inlet.

Once all data were collected, they were downloaded to a personal computer, post-processed, viewed, and edited. These data were then exported to ARC/INFO and cleaned, and a coverage was created following the procedures previously outlined by Brich and Fitch.[4] The coverage was then transferred to ArcView for final display (see Figure 10).

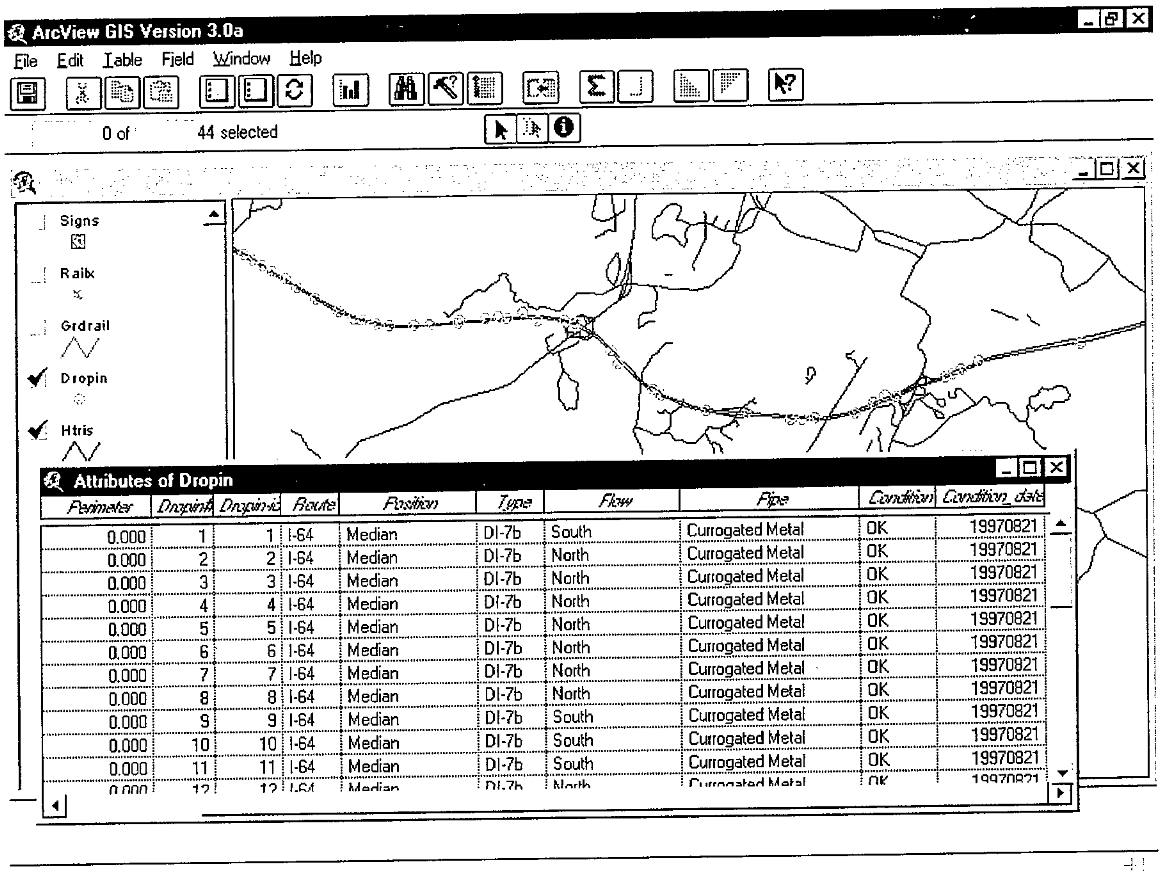

Figure 10. Drop inlet application coverage

Drop Inlet Inventory Time and Effort

A total of 44 inlets were inventoried in the development of the drop inlet inventory. This coverage development took approximately 176 minutes, or 4 minutes per feature. The time required to collect any one feature varied significantly and was highly dependent on the terrain (i.e., mowed median versus heavily vegetated median) and the visibility of the feature. The

researchers considered 4 minutes per feature a reasonable average given that visual inspection was required to collect the data. For debris-covered drop inlets, the majority of the time will be spent attempting to locate them.

Mowing Area Calculation

Determining the optimal way to calculate interstate mowing area was undoubtedly the most difficult of the five priority applications. This effort did not involve collecting attribute data but simply entailed calculating how many hectares of grass were to be mowed for any given segment of interstate. Accurate calculation is important because VDOT contracts the majority of interstate mowing. Contractors are paid on a per hectare basis. This rate can vary widely for different areas of the state (the average is approximately $99/hectare) for mowing services.[6] Originally, the idea of digitizing the areas to be mowed along the interstate from aerial photographs appeared promising. However, because of the scale of the photographs available (1:6000), it was impossible to delineate the mowed edge along the roadside. Photographs of sufficient scale and resolution could be obtained, but they would likely be cost prohibitive, based on the costs of the photos that were purchased and the number required for even this study area.

The number of mowing swaths (width of approximately 2 m) for a given mile segment was available from the graphic logs. Although not very accurate (it gives the number of swaths for an entire mile), this information is useful and is probably the best source of data for the residency at this time. The researchers experimented with GPS as a means of collecting data about interstate mowing areas. As in some of the other data sets, walking the perimeter of the mowing area resulted in very accurate information but proved to be too slow and labor-intensive. This method was also dangerous, since the data collector had to walk, unprotected, only 1 to 2 m from traffic moving at normal highway speeds.

The researchers also tested an approach that used a GPS in conjunction with a laser range finder. The researchers drove the GPS antenna along the right shoulder (the edge of pavement) and used the laser range finder to measure the distance to the far edge of the mowed area. This method was extremely slow and cumbersome, and the data collected were subject to large errors. It was also nearly impossible to collect the information for the median because of conflicts that occurred when the researchers attempted to combine manual and laser-derived offsets in the same data set. The final means for determining the mowing area consisted of simply using the laser range finder to calculate the distance from the edge of pavement to the edge of the mowed shoulder. This same method was used for the median (see Figure 11).

Data Collection

The technique using the laser range finder was the simplest of all methods tested. With the driver starting at a known point (interchange or mile marker), they drove the van along the edge of the right shoulder. Each 0.16 km (0.1 mi), as determined by the vehicle's odometer or a distance measuring instrument (DMI), the range finder was pointed and triggered to calculate the distance to the back edge of the mowed area. This distance was manually recorded and the

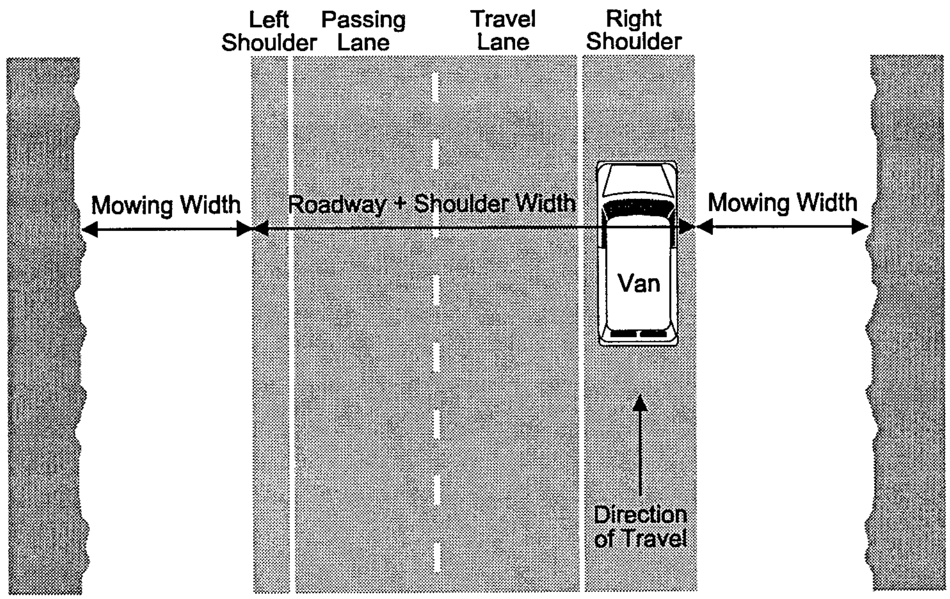

Figure 11. Mowing Area Calculation Method

procedure repeated until the next interchange was reached. The van driver maintained a set speed of approximately 40 to 56 km/h (25 to 35 mph), and the laser operator recorded the data. The same technique was used for measuring the mowed area in the median. The van was driven on the right shoulder, and the laser shot across the vehicle and lanes of traffic. The width of the lanes and shoulders had to be subtracted from the value obtained with the laser. This same procedure could be carried out from the passing lane, provided proper traffic control was available. Also, the collection interval could be increased or reduced depending on the time constraints of the collectors and the variability in the terrain.

For this particular application, no GIS coverage was developed. Rather, a numeric value was obtained for each 1.6-km (1-mi) segment of interstate. A coverage could be developed by averaging the mowing widths and creating a buffer based on the road network. Because no attribute data are associated with the segments, the researchers decided not to create the coverage.

Although the data were stored manually during this test, the range finder used could have been connected to a laptop computer and the data immediately transferred to it by way of the RS-232 output. This setup, used in conjunction with a DMI, would provide the width measurement and a corresponding distance from the starting point. Although time did not permit the complete testing of this particular collection method, it is certainly technically feasible.

Mowing Area Calculation Time and Effort

Using the method described, it is estimated that for each 1.6 km (1 mi) of interstate, the mowing area could be developed in approximately 14 minutes. This estimate includes measuring both sides of the roadway (right shoulder and median) enter the data into a spreadsheet. It does not account for time needed to measure the mowing area for the ramps associated with interchanges. Because of the variation in the area mowed for each of these, it is estimated that collection time would be significantly slower for these areas. Time spent on this could increase or decrease significantly based on the density of the measurements taken (0.16 km [0.1 mi] for this example). If the data from the laser and the DMI were automatically downloaded to a laptop computer, it is assumed that the time required would be less than half of the 14 minutes/mile.

Railroad-Highway Grade Crossing Inventory

This particular application was developed in a manner different than the previous four. In a study published in 1996, the researchers demonstrated how GPS could be used to collect highway inventory data.[3] In one of the case studies conducted as part of the 1996 study, the researchers developed an inventory of railroad-highway grade crossings in Albemarle County and the City of Charlottesville. The researchers used a GPS receiver to collect the crossing's location and its unique identifier (DOT-AAR number). No other attribute information was collected at that time.[3]

Since the information had already been collected and was in a digital file, the researchers decided to add a functional railroad-highway grade crossing priority application to the list of GIS applications already under development. The previously collected information was updated to include the information contained in VDOT's legacy database, the Highway and Traffic Records Information System (HTRIS).

Database Development

HTRIS contains, among other elements, all of the information related to the railroad-highway grade crossing inventory. The researchers decided to download this data into a PC database format (*.dbf). VDOT's Traffic Engineering Division (TED) staff provided this service. The researchers then pulled the database file into an Excel spreadsheet for manipulation, eliminating any unnecessary fields as identified by TED staff. After making minor modifications, the researchers exported the file as an ASCII comma delimited text file.

Next, the ASCII file was transferred to a newly created ARC/INFO file so that the attribute values could be read by the GIS. The INFO file's characteristics were defined using similar column widths and parameters as specified in the *Railroad Subsystem Users Manual* for HTRIS.[7] Once the INFO file's characteristics were defined, the ASCII file was added to the INFO file and the resulting file was then combined with the existing ARC/INFO coverage. This process produced a fully functional railroad-highway grade crossing GIS application. Combining the previously developed coverage with the values found in the legacy database, the application has more than 2,500 grade crossing attributes for the 27 crossings in the study area. Figure 12 depicts the location of the crossings in Albemarle County and displays a portion of an attribute file for a single crossing.

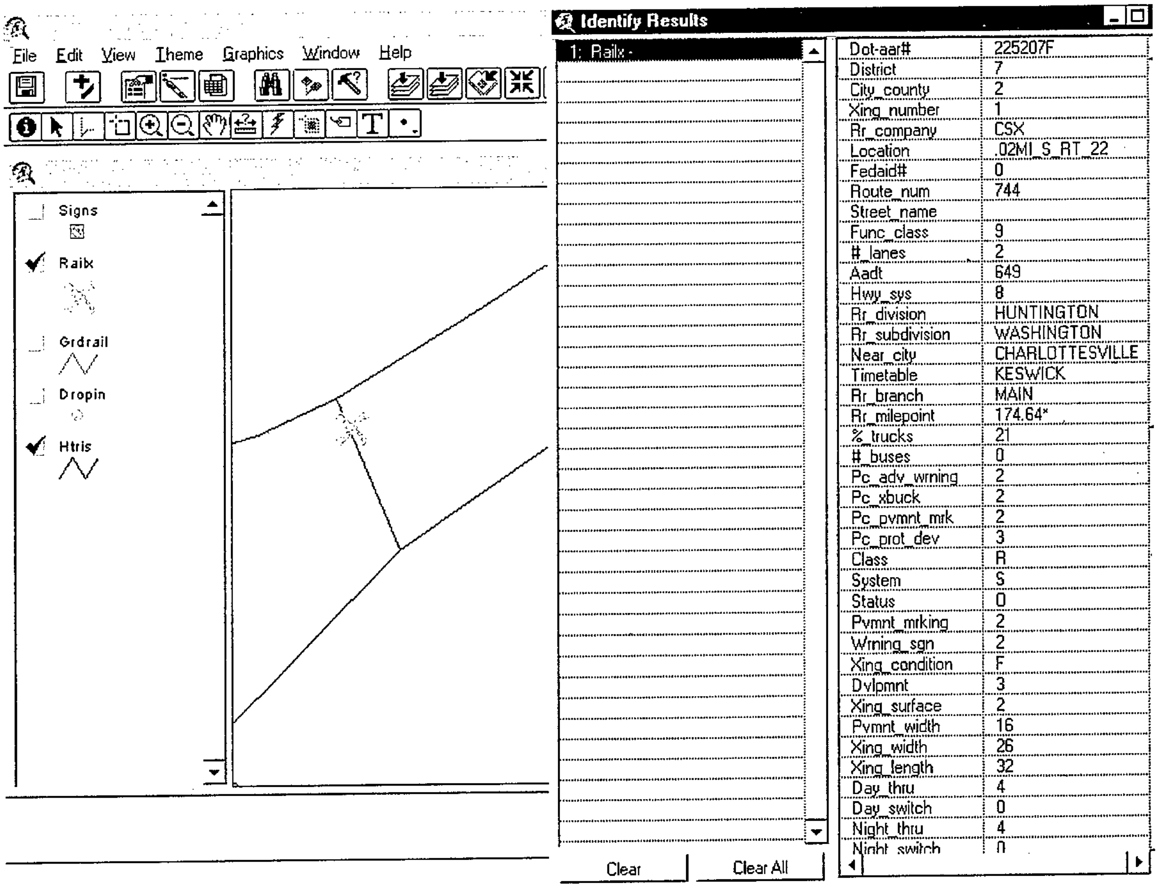

Figure 12. Railroad-Highway Grade Crossing Application Coverage

CONCLUSIONS

- *ICAS data requirements provide an excellent foundation for a GIS.* However, for that data to be usable by residency and district staff, additional attribute information, in most cases, is required for each asset type.

- *To make the GIS useful for residency applications such as inventories, data must be very detailed.* Most affordable remote sensing sources, e.g., satellite imagery or aerial photographs, are not of sufficient resolution to meet residency needs. The data required for a residency-level GIS will almost have to be captured using GPS and visual observations exclusively. In most cases, this method of data collection is more time-consuming, labor-intensive, and costly than remote sensing, but the end product is more accurate and more beneficial.

- *For most of the priority applications developed in this study, GPS proved to be the best mode of data collection.* GPS enables accurate spatial information collection and extensive attribute storage. It allows for a one-step data transfer process to almost any given GIS platform, which means data are available for use almost immediately.

- *Much of the information collected on features in this report and those that are specified in ICAS would need to be inventoried only once, since the features do not typically change over time.* Subsequent condition assessments could be performed without having to re-inventory the entire asset group. Conceivably, a portable computer with a GIS could be used to update asset information in the field. In the case of new installations, a GPS receiver could be used to update the inventory at that time. In contrast, use of aerial photographs or graphic logs as the source of information would require that these data sets be recollected in their entirety to update the data sets.

- *To ensure accurate results, the method of data collection must be determined as carefully as the mode of collection.* For example, in the case of the guardrail application, GPS was determined to be the correct mode of collection. However, the researchers had to develop two methods of using GPS, one for the interstate and one for the primary roadway inventory, because the offset requirements differed. To ensure that the results are comparable, these data collection methods need to be standard across residencies.

- *The applications developed demonstrate how a GIS can be used, giving residencies throughout VDOT a better understanding of the types of tasks to which this technology can be applied.* The methods used to collect the spatial and attribute data will serve as a guide to future GIS developers when they collect similar data sets. The time estimates allow each residency to evaluate the approximate cost and effort required to acquire the data needed to support a GIS.

RECOMMENDATIONS

1. *The GLU should standardize all modes and methods of spatial and attribute data collection for the development of a residency level GIS.* This would ensure uniform spatial accuracy and attribute content, allowing the transfer and analysis of like data sets to district and central office personnel.

2. *The GLU should consider adopting an approach to determining the methods to collect the maintainable asset information similar to that described in this report.* No single method will provide VDOT with accurate information for each maintainable asset. Conceivably, VDOT could be faced with having a specific mode and method of collecting the information for each type of asset.

3. *The GLU and VDOT's Maintenance Division may wish to use the time estimates generated in this study to gauge the time and costs associated with developing these applications on a statewide basis.*

4. *The GLU should identify and develop other priority applications to be used by the residency to reduce the per application development cost and allow the full potential of the GIS to be realized.*

5. *The GLU should remain abreast of new data collection technology to increase the efficiency and accuracy with which data can be collected.*

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APPENDIX A

Guardrail Data Dictionary

Guardrail Inventory Data Dictionary (Line Feature)

Attribute	Type of Input	Value
Route Number	Menu	I-64
		6
		20
		22
		29
		29B
		53
		151
		231
		240
		250
		250B
Direction	Menu	North
		South
		East
		West
Rail Location	Menu	Left
		Right
Material Type	Menu	Metal
		Cable
Run-on End Treatment	Menu	GR-3
		GR-5
		GR-6
		GR-7
		GR-8
		GR-9
		GR-FOA-1
		GR-FOA-2
		GR-FOA-4
		Radial Flared
		Radial Buffer
		Radial Rounded
		Flared
		Buffer
		Rounded
Running Section	Menu	GR-2
		GR-8
Delineators	Menu	Run-On
		Run-Off
		Running
		Full
		None
Location Delineators	Menu	Top
		Center
		Both
		None
Condition	Menu	OK
		Repair
		Replace
Date of Assessment	Automatic Generation	Month-Day-Year
Run-Off End Treatment	Menu	GR-3

		GR-5
		GR-6
		GR-7
		GR-8
		GR-9
		GR-FOA-1
		GR-FOA-2
		GR-FOA-4
		Radial Flared
		Radial Buffer
		Radial Rounded
		Flared
		Buffer
		Rounded
Height of Rail	Numeric	Min=0, Max=100

APPENDIX B

Sign Data Dictionary

Sign Inventory Data Dictionary (Point Feature)

Attribute	Type of Input	Value
Route	Menu	I-64
Direction of Travel	Menu	West
		East
		North
		South
Position	Menu	Right
		Left
		Overhead
Type	Menu	6E9
		D10-3
		R6-1
		E1-5
		E5-1a
		E1-1
		E4-1
		W13-2
		R8-3a
		W4-1
		R8-7
		VR-18
		D5-2
		G-25
		G-24
		D9-7
		M3-4
		M3-2
		M1-1
		R2-1
		VG-27
		E7
		R8-7
		W11-3
		E9
		VG-21c
		E5-1
		E5-2
		VG-29
		I-5
		D9-8
		D9-16
		E1-3
		VG-30
		D9-2
		D12-3
		D5-1
		D9-1
		D9-6
		W12-2
		D1-1
		R4-3
		VW-9
		D6-2
		D6-3
Condition	Menu	OK
		Repair
		Replace
Condition Date	Auto generate	Month – Day- Year

APPENDIX C
Drop Inlet Inventory

Drop Inlet Inventory Data Dictionary (Point Feature)

Attribute	Type of Input	Value
Route	Menu	I-64
Position	Menu	Median
		WB Shoulder
		EB Shoulder
Type	Menu	DI-7b
		DI-7a
		DI-7
		DI-5
Flow	Menu	South
		North
		North/South
		East
		West
		East/West
Pipe	Menu	Corrugated Metal
		Concrete
Condition	Menu	OK
		Repair
		Replace
Condition Date	Auto Generate	Month – Day - Year