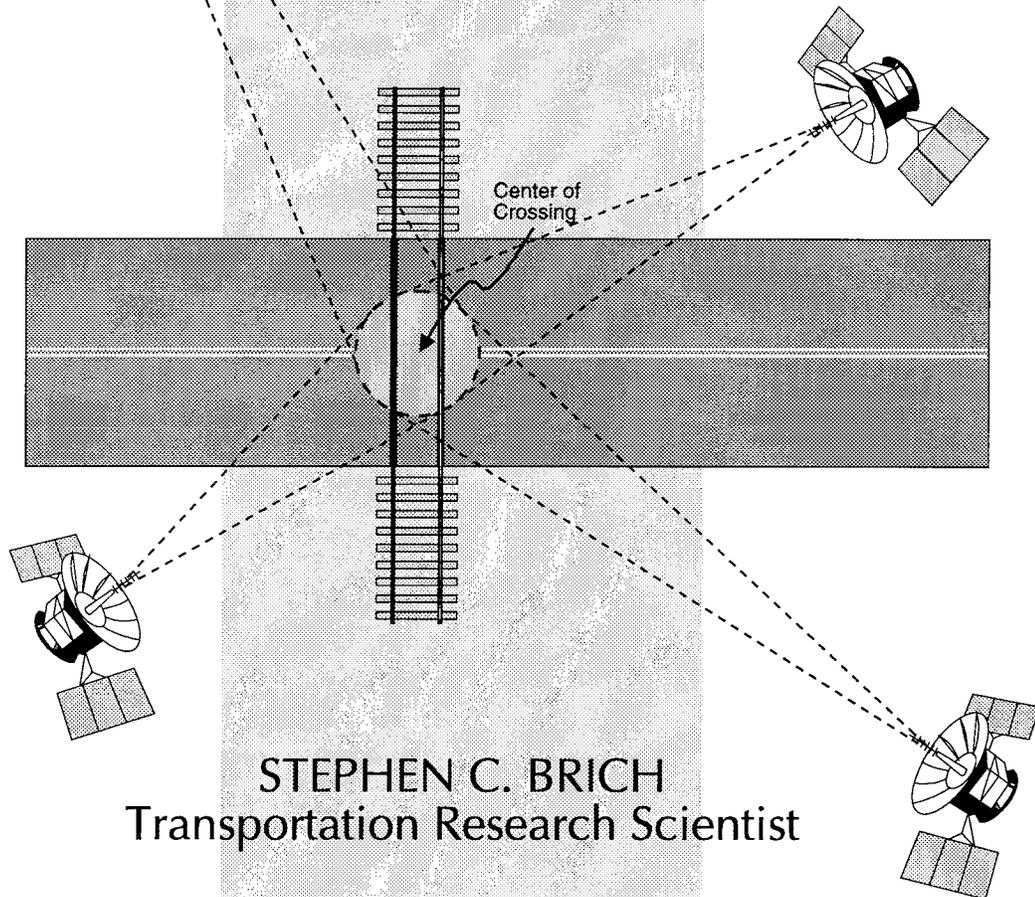FINAL REPORT

CASE STUDIES IN COLLECTING HIGHWAY INVENTORY DATA WITH THE GLOBAL POSITIONING SYSTEM

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Crossing

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16. Abstract

A number of state departments of transportation, including the Virginia Department of Transportation (VDOT), are developing a geographic information system (GIS) to integrate data and to conduct more elaborate analyses which will improve their decision-making capabilities. Research is currently being conducted at the Virginia Transportation Research Council to determine some of the problems associated with the implementation of this relatively new and evolving technology. The collection and development of the data sets required to drive the GIS have been identified as two of the largest expenses associated with GIS implementation. This research looked at the feasibility of using the Global Positioning System (GPS) to collect some of the locational and attribute data required to run VDOT's GIS.

Data sets identified in VDOT's 10-Year GIS Strategic Plan were collected and transferred to ARC/INFO®, a proprietary system, by way of hand-held, mapping-grade GPS receivers. Methods for the collection and transfer of the data sets were outlined. Point accuracies of approximately 2 m were obtained. Time requirements and data collection problems were also described. These findings should ultimately aid VDOT in its GIS implementation process.

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(The opinions, findings, and conclusions expressed in this
report are those of the authors and not necessarily those of
the sponsoring agencies.)

DEFINITION OF TERMS[*]

ARC/INFO®

A GIS software package developed by Environmental Systems Research Institute, Inc.

Attribute

Characteristics of features in a geographic information system (GIS) or Coordinate GeOmetry (COGO) package. Every identifiable feature has attributes. One common attribute of all survey features is geographic position. For example, a road has a name or designated number, surface type, width, number of lanes, and so on. Each attribute has a range of possible values, called a domain. The value chosen to describe a particular feature is called the attribute value.

Attribute Value

A particular value for a feature, chosen from the domain of an attribute. For example, surface type is an attribute; bitumen, gravel, and concrete are a domain; and gravel is an attribute value.

Base Station

Also called a reference station. A receiver that is set up on a known location specifically to collect data for differentially correcting rover files. The base station calculates the error for each satellite and, through differential correction, improves the accuracy of GPS positions collected at unknown locations by a roving GPS receiver.

Coverage

A digital version of a map forming the basic unit of vector data storage in ARC/INFO.® A coverage usually represents a single theme, or a layer, such as soils, streams, roads, or land use.

Data Dictionary

Information that describes features that will be located in the field. This description includes features names, data type classification (point, line, or area), attribute names, attribute types, and attribute values. After being created on a PC, a data dictionary is downloaded to a datalogger and used when data are collected in the field.

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[*]These definitions were derived from the following references: Trimble Navigation Limited. March 1994. *Mapping Systems General Reference.* Sunnyvale, Calif.; Environmental Systems Research Institutes, Inc. 1994. *Understanding GIS: The ARC/INFO® Method.* Redlands, Calif.; J. G. Lyon and J. McCarthy (eds.). 1995. *Wetland and Environmental Applications of GIS.* New York: Lewis Publishers (CRC Press, Inc.); and E.D. Kaplan (ed.). 1996. *Understanding GIS: Principles and Applications.* Norwood, Mass.: Artech House, Inc.

Datalogger

Also called a data recorder. A hand-held, lightweight data entry computer. The datalogger used in this study was a Trimble GeoExplorer™ GPS receiver.

Differential Correction

The process of correcting GPS positions at an unknown location with data collected simultaneously at a known location (base station). The process of differentially correcting one receiver's location relative to another's can be done during post processing.

In post-processed differential GPS (DGPS), the base station logs the measurements in a computer file so rover users can differentially correct their data upon return to the base station.

Epoch

Measurement interval or data frequency in making observations. For example, if data are measured every 15 sec, loading data using 30-sec epochs means loading every other measurement.

Feature

A physical object or location of an event. Features can be either points (a tree or a traffic accident), lines (a road or a river), or polygons (a forest or a parking lot).

Global Positioning System (GPS)

The GPS consists of a constellation of 24 satellites (called NAVSTAR, from NAVigation Satellite Timing And Ranging) arranged in six orbital planes with 4 satellites per plane. Each satellite orbits the earth once every 12 hr at an approximate height of 26600 km. The system provides accurate, continuous, worldwide, three-dimensional position and velocity information to users with the appropriate receiving equipment. GPS can provide service to an unlimited number of users since the user receivers operate passively (i.e., only receive). A GPS receiver calculates its position by using the known location of each of the satellites from which it is receiving signals and the time it takes for the signal to travel from each of the satellites to the receiver. This information determines the distance from each satellite to the receiver. Signals from 4 different satellites are required to calculate the position of the GPS receiver by solving for unknowns: latitude, longitude, altitude, and time. This position calculation process is known as trilateration.

Line

A set of ordered coordinates that represents the shape of geographic features too narrow to be displayed as an area at the given scale (e.g., contours, street centerlines, streams) or linear features with no area (e.g., state and county boundary lines).

Lock	To track a satellite.
Multipath	Interference similar to ghosts on a television screen that occurs when GPS signals arrive at an antenna having traversed different paths. The signal traversing the longer path yields a larger pseudorange estimate and increases the error. Multiple paths can arise from reflections off structures near the antenna.
Multipath Error	A positioning error resulting from interference between radio waves that have traveled between the transmitter and the receiver by two different paths of different electrical lengths.
Point	A single x,y coordinate that represents a geographic feature too small to be displayed as a line or an area, e.g., the location of a tree or sign.
Polygon	A multisided figure that represents an area on a map.
Raster	A cellular data structure composed of rows and columns. Groups of cells represent features. The value of each cell represents the value of the feature. Each cell must be rectangular, but not necessarily square.
Receiver	A device that processes the signals transmitted from the satellites to determine the user's position, velocity, and time (PVT). A receiver typically consists of five principal components: antenna, receiver, processor, input/output device, and a power supply.
Rover	Any mobile GPS receiver collecting data during a field session. The receiver's position can be computed relative to another stationary GPS receiver.
Post Processing	See Differential Correction.
Selective Availability	Artificial degradation of the satellite signal by the U.S. Department of Defense (DOD). A DOD program to control the accuracy of pseudorange measurements where the user receives false pseudorange in error by a controlled amount. The error in position caused by selective availability (S/A) can be up to 100 m. Differential GPS techniques can reduce these effects for local applications.

UNIX

A computer operating system that controls the flow of data, the application of other programs, the organization and management of files, and the display of information.

Vector

A coordinate-based data structure commonly used to represent map features. Each linear feature is represented as a list of ordered x, y coordinates. Attributes may be associated with a feature (as opposed to a raster data structure, which associated attributes with a grid cell).

ABSTRACT

A number of state departments of transportation, including the Virginia Department of Transportation (VDOT), are developing a geographic information system (GIS) to integrate data and conduct more elaborate analyses that will improve their decision-making capabilities. Research is currently being conducted at the Virginia Transportation Research Council to determine some of the problems associated with the implementation of this relatively new and evolving technology. The collection and development of the data sets required to drive the GIS have been identified as two of the largest expenses associated with GIS implementation. This research looked at the feasibility of using the Global Positioning System (GPS) to collect some of the locational and attribute data required to run VDOT's GIS.

Data sets identified in VDOT's 10-Year GIS Strategic Plan were collected and transferred to ARC/INFO®, a proprietary system, by way of hand-held, mapping-grade GPS receivers. Methods for the collection and transfer of the data sets were outlined. Point accuracies of approximately 2 m were obtained. Time requirements and data collection problems were also described. These findings should ultimately aid VDOT in its GIS implementation process.

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INTRODUCTION

A geographic information system (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to provide for the efficient capture, storage, update, manipulation, analysis, and display of all forms of geographically referenced information.[1] A number of state departments of transportation, including Connecticut, Pennsylvania, Michigan, Minnesota, and North Carolina, are developing GISs to integrate data and conduct more elaborate analyses, which will improve the decision-making capabilities of the agencies. The Virginia Department of Transportation (VDOT) is also implementing a GIS to improve their decision-making process. VDOT recently developed a 10-Year GIS Strategic Plan that will be used as a "road map" to acquire the necessary tools and devise the proper organizational structure for a departmentwide GIS.[2]

GIS implementation for an agency as large and diverse as VDOT is extremely complex and time-consuming. A GIS Steering Committee was created in November 1988, and a private consultant was contracted to develop a strategic plan to guide VDOT's GIS implementation. With the recent completion of this plan, 10 priority applications were identified that will be the pilot projects for future applications. A major component in the implementation of these applications is the acquisition of data. Hardware and software can be acquired more quickly than data sets. Also, with few exceptions, the hardware and software used for different applications will have features in common. The data sets, however, will be at least somewhat dependent on the specific application being developed. Therefore, data acquisition is one of the most important, and one of the most expensive, steps in the GIS implementation process.

Estimates for the cost of database development for a GIS are said to range from 50 to 80 percent of the cost of GIS implementation.[3,4] Although these estimates include database design and maintenance, data acquisition comprises a large portion of this cost. The method used to acquire data affects both the cost of acquisition and the quality of the data set. There are many ways to capture or transfer data in a digital format so they can be used by a GIS. Some of the more common technologies used to collect data include the **Global Positioning System**[*] (GPS),

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[*]Terms displayed in **bold** are defined in "Definition of Terms" on page iii.

video, digital photography, softcopy photogrammetry, high-resolution satellite imagery, high-resolution document and image scanners, manual digitization of hard copy data, and real-time systems and sensors.[5] Each technology has advantages and disadvantages that are somewhat dependent on the data set being collected. In addition, particular data sets are now available through commercial vendors.

Video, digital photography, softcopy photogrammetry, high-resolution satellite imagery, and all image scanning capture data in a **raster** format. Unfortunately, although most high-end GIS software packages can handle raster data sets, they cannot normally be queried against **vector** data sets. This is because the raster format associates **attribute values** with a grid cell and the vector format associates **attribute** data with a specific **feature** (i.e., point, line, or polygon). All data that will be combined or analyzed need to be in a common format, which, because of its efficiency, is normally a vector format. Most data collected in a raster format must be converted into a vector format before being used by a GIS, a process that is extremely time-consuming, imprecise, and expensive.

Manual digitization and the use of the GPS result in vector-formatted data. Both methods are very reliable and relatively accurate (although digitization depends on the source being digitized). Both are also labor intensive and time-consuming. Digitization is very versatile, but it does require that the data already exist in some type of hard copy format. GPS data collection is based on recording the current position of the GPS receiver. Some of the known benefits of this technology are its ability to handle very large data sets, the speed with which data can be collected, its ability to attach attribute information to the feature while the feature is being collected, and the relatively low cost of the hardware. GPS technology has advanced rapidly in the last few years and is potentially one of the best methods of data capture.

VDOT's GIS Strategic Plan[2] focuses primarily on computing requirements, the conceptual framework, data sharing, organization and staffing needs, strategic trends, and priority applications. The plan also identifies what a GIS can accomplish after the information has been fully integrated into the system. The means of data collection, conversion, correlation, and integration are addressed only on a very general level, with few specifics given. Therefore, there is a need to determine which data collection methods are applicable for particular data sets that will eventually be required for VDOT's GIS.

PURPOSE AND SCOPE

The primary purpose of this project was to determine the feasibility of and develop procedures for using the GPS to collect selected data sets that will be required to implement the priority applications identified in VDOT's GIS Strategic Plan.[2] The development of correct procedures early in the implementation process will reduce the start-up time for GIS implementation and thereby help VDOT realize the many benefits of using GIS sooner.

FIGURE 1. GEOEXPLORER™ GPS RECEIVER

A GeoExplorer™ GPS (mapping grade) receiver from Trimble Navigation, Ltd. was used as the **datalogger** in this study (Figure 1). The technology used in these receivers is basically the same as that used in other receivers, and the results should not vary significantly with the use of another manufacturer's receiver. Although a limited number of applications and data types were selected for study, those chosen adequately represent the types of data to be collected, the ease of collecting data, the accuracy of the data, the processes used to correct the data, and the processes used to incorporate the data into a **UNIX**-based **ARC/INFO**® GIS.

METHODS

Literature Review

A computerized literature search was conducted to identify literature on using GPS for data collection and its transferability to a UNIX-based GIS. This literature, VDOT's GIS Strategic Plan, and other documents pertaining to VDOT's implementation of GIS were reviewed.

Interviews

The researchers supplemented the literature by holding informal meetings with three VDOT resident engineers in central Virginia to gain insight into the potential uses for a GIS at

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the operations level. These interviews proved useful in developing the list of data types for collection.

Selection of Applications and Types of Data Sets To Be Collected

VDOT's GIS Strategic Plan, prepared by Michael Baker and Associates, identified the priority GIS applications VDOT should focus on for the development of a departmentwide GIS over the next 1 to 3 years.[2] These applications are listed in Table 1. The applications were identified as having priority after the consultant analyzed VDOT's business activities, operations, and initiatives. The consultant also stated that "in order for VDOT to expand and enhance current GIS operations so that a Department-wide solution can be determined, certain needs will have to be met, particularly for the implementation of the priority applications identified . . . ."[2] One of the three needs identified was "GIS Data Needs." That is, different types of data will be required to support the priority applications. The plan offered no clear suggestion on the data needed to drive these applications or the methods required to collect the data.

The researchers selected three applications from the list of priority applications and three representative data sets for which data collection could be carried out using the GPS. The

TABLE 1
PRIORITY APPLICATIONS

Number	Priority Application
1	Safety Management System
2	Compliance with the National Environmental Policy Act (NEPA) and Water Quality Regulations (network level)
3	Pavement Management System
4	Bridge Management System
5	Operations and Maintenance (network level)
6	Fiscal Applications
7	System Planning Applications
8	Project Planning
9	Compliance with the NEPA and Water Quality Regulations (project level)
10	Operations and Maintenance (project level)

applications selected were (1) Safety Management System (SMS), (2) Operations and Maintenance, and (3) Compliance with the National Environmental Compliance Act (NEPA). The three data sets selected were those for each GPS feature type: **point, line,** and **polygon.**

The data collection process was monitored for the time required to complete the in-field data collection using GPS, the **differential correction** of the information, and the inputting of the information into the GIS. These steps and their associated times will provide useful information to those managers assigning data collection teams to collect, download, and prepare the information for use in a GIS.

Point Data for the SMS: Highway-Railroad Grade Crossings

The development of an SMS on a GIS platform will require significant amounts of existing data and the collection of new and more accurate pieces of information. To complement the SMS, all public highway-railroad grade crossings in Albemarle County and the City of Charlottesville were collected as point data. Each crossing location was collected, and its unique identifier (DOT-AAR number) was recorded in the GPS receiver's **data dictionary** to identify the crossing in the office.

Line Data for Operations and Maintenance: Adopt-a-Highway Program

VDOT's GIS Strategic Plan identified operations and maintenance as requiring a "large quantity of items to be collected."[2] One item continuously raised during the interviews with the resident engineers was the management of the Adopt-a-Highway (AAH) program and the location of AAH segments. All of the AAH segments in Greene County were collected as line data. The names and route numbers of the segments were recorded in the receiver's data dictionary to identify the segment in the office.

Polygon Data for Compliance with the NEPA: Wetland Delineation

Compliance with NEPA will require VDOT to collect and monitor a variety of environmental data sets. The location of wetlands created by VDOT for mitigation purposes could potentially be a needed data set. GPS was used to collect the boundary of a single created wetland site in Greensville County. Since only the boundary of the site was collected, the data were stored as a polygon. No attribute data were stored with the location information.

GPS Parameters

Receiver Settings

The Trimble GeoExplorer™ allows the user to adjust the parameters that affect the way it collects and stores information. There are 22 user-defined **rover** settings. The default settings for this particular receiver were used in all but one instance. The following values were used for the most important settings:

- *Feature logging:* allows the user to specify the type of data being collected and how often the positions are stored. The point data were collected at 1-sec intervals, which is the default setting. The line features were also collected using 1-sec intervals even though 5-sec intervals is the default. This setting was chosen to produce more information, primarily because of the alignment of the roadway segments (sharp turns and an abundance of curves) encountered, the canopy cover, and the mountainous environment of most of the secondary roads encountered.

- *Elevation mask:* sets the minimum elevation above the horizon for a satellite to be used in the position calculation. The rover mask was set at 15°, the default.

- *Signal-to-noise ratio (SNR) mask:* allows the user to specify the minimum signal strength from a satellite before the signal is recorded. The default value was used.

- *Position dilution of precision (PDOP) mask:* sets the maximum error allowance of the recorded satellite positions. The default value was used.

Data Dictionary

A data dictionary was developed for the point and line features investigated. A data dictionary is no more than a user's pre-built structure to input attribute values for a particular feature.[6] Most GPS receivers that allow for the storage of position data also allow for the input of attribute data by way of a data dictionary. For example, when a stop sign inventory is conducted, the type of material the post is constructed of (wood, metal, etc.) can be input as attribute data in the data dictionary. Additional attribute values that the user may want to build into the data dictionary for a stop sign inventory include the type of sheeting used, the size of the sign, and the date the sign was installed. This structure can be built in the office so that the user can simply input whether the sign is supported by wood or metal, its type of sheeting, and the date it was installed. The data dictionary is capable of handling user-defined menu values, numeric attribute values, date attribute values, character attribute values, and time attribute values. The text string for the character attribute values may contain alpha and/or numeric characters.

The data dictionary developed for the highway-railroad grade crossing section was one that accepted alphanumeric values. This is because the primary goal of the researchers was to enter the location of the crossing and its DOT-AAR number. The researchers developed the dictionary to hold 6 numbers and 1 alphabetic character. This allowed them to enter the attribute (DOT-AAR number) for the crossing while the receiver was recording points locating the crossing.

A data dictionary was also created for the AAH line feature. This dictionary was developed to have the user enter two attributes for each feature: (1) the name of the group responsible for the roadway segment and (2) the route number for the segment. The researchers developed the dictionary to hold the name of the AAH segment using the character attribute values capable of handling up to 12 characters and the route number using the numeric attribute value to 4 places.

Determination of Accuracy

To supplement the feature data collection activities and address the issues surrounding the accuracy of the data, the researchers conducted three sets of experiments. The first experiment involved determining the accuracy of point data using a known Geodetic Control Point High Accuracy Reference Network (HARN) monument. This HARN monument, number AIG1, was surveyed by the National Geodetic Survey and is located in northern Albemarle County. The exact coordinates for this location are known and documented. To determine the accuracy of the GPS receiver, a receiver was placed directly over the monument and allowed to collect and store signals for a minimum of 120 points. This method replicates the procedures used in the collection of the highway-railroad grade crossings. The researchers recorded the HARN site 10 times in 10 different files.

The second experiment used the same HARN monument to determine the accuracy of the line features. The researchers developed an equilateral triangle with the HARN location representing one corner of the triangle and each leg of the triangle being 45.72 m (150 ft) in length (Figure 2). The side of the triangle opposite the HARN was collected using the GPS receiver. This segment was used to determine the segment's length and distance from the known point using GPS. The line segment was recorded 10 times in 10 different files.

The third experiment used the same equilateral triangle (Figure 2). After the GPS file was opened, approximately 120 points were collected at each corner of the triangle and the file was then closed. This procedure was carried out 5 times, resulting in 5 files representing the same polygon area. The files were then **post processed** and grouped using the PC software package provided with the receiver. The points making up each file were then connected to form 5 polygons. The area calculations for each polygon, as well as their respective location, were then compared.
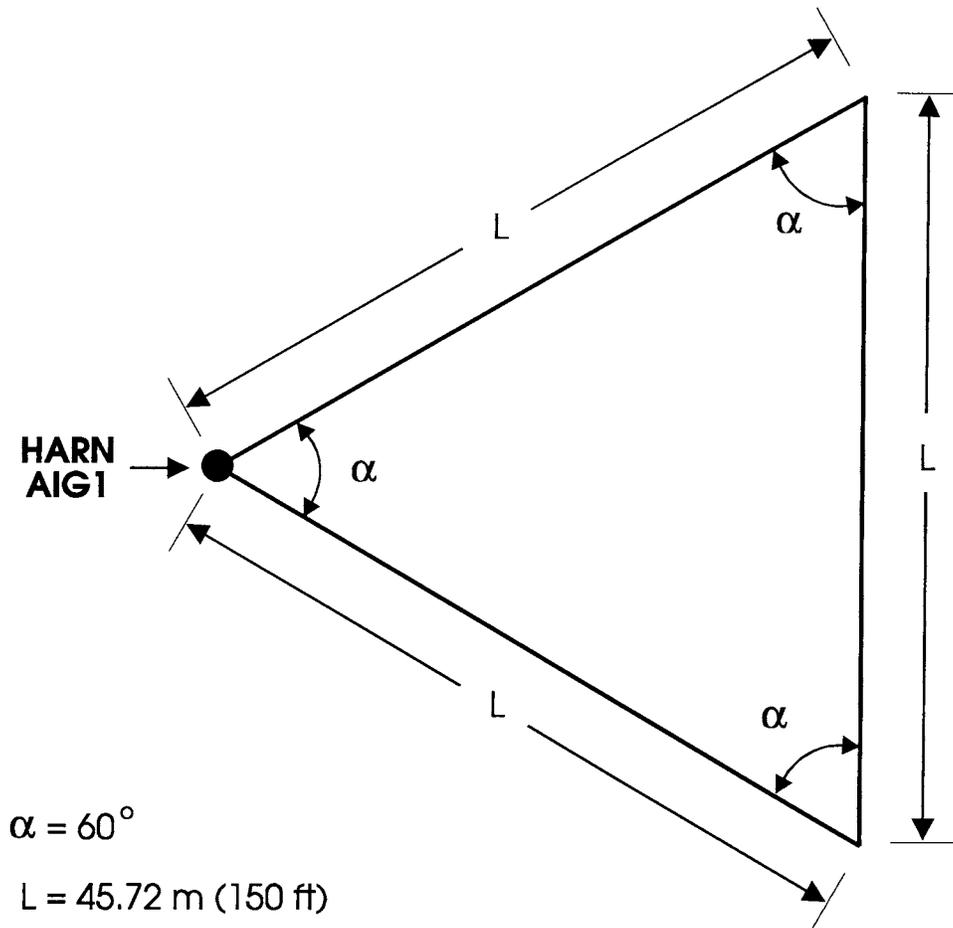
HARN
AIG1 →

α = 60°

L = 45.72 m (150 ft)

FIGURE 2. HARN LOCATION AND EXPERIMENTAL TRIANGLE

RESULTS

Literature Review

As the popularity of GIS as a management tool has grown nationally, research has been initiated to determine appropriate methods to collect the data that drive these systems. By far, the most expensive part of any GIS is the initial data collection and the constant updating of the ever-evolving data sets. Most of the very limited research done with respect to GPS as a data collection mechanism evaluated the technology in three areas: accuracy, cost, and reliability or ease of use.

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Accuracy

Most GPS vendors indicate that data collected with receivers is accurate to within 2 to 10 m, depending on a number of variables. Research conducted by Hyman et al.[7] for the Arizona Department of Transportation found that uncorrected data (not undergoing differential correction) had errors of nearly 100 m. After determining that these data did not meet the location accuracy of 16 m needed for their sign management system, they expanded their study to include differential GPS (DGPS). With DGPS, errors between 2 and 5 m were obtained.[7] Hook et al.[8] found in their use of GPS for the collection of wetland boundaries that overall accuracies were on the order of 5 m. Similar work by McGarigle[9] had accuracies ranging from 2 to 5 m, depending on the receiver's distance from the **base station** used to post process the data. The values for the work of both Hook et al. and McGarigle included differentially correcting the GPS-collected data.

In addition to differential correction, the other important variable determining the accuracy of GPS-collected data is the number of **epochs** or signals recorded for a particular point. Most manufacturers recommend that between 120 and 180 epochs be recorded and then averaged to determine the location of a single feature. Several studies, however, have found that between 10 and 60 epochs still result in errors of less than 5 m.[8,10,11]

Costs

Most research on the feasibility of GPS to collect data for GIS did not consider the cost of data acquisition beyond simply factoring in the purchase price of the receiver. This price ranged from $4,000[7] to $15,000.[11] Poling et al.[11] did compare the staff hours associated with collecting sign inventory data with GPS and the staff hours associated with manual measuring with a measuring wheel. Both types of data were then taken back to the office for transfer into a GIS. The researchers found that although data collection with GPS took more time in the field (4 min per feature as compared to 2.6 min per feature for manual measurement), it required less time to post process and import into the GIS (0.6 versus 2.9 min). In the research conducted using DGPS, the researchers included the price of the receivers used as base stations. These are generally more expensive than receivers used for field data collection and are not necessary, assuming public base stations are made available. Hyman et al. warned that the use of GPS requires careful implementation to ensure that the costs of acquiring the equipment do not exceed the benefits that will be realized. Finding additional applications for the data and its manipulation will ensure that the benefits do outweigh the costs of the equipment.[7]

Reliability/Ease of Use

Several other criteria were used in the limited research designed to determine the ease of use of GPS for GIS data collection. Hyman et al. wanted to determine (1) if technicians or field

personnel could use the GPS technology since they are typically responsible for most data collection, and (2) how much training would be required for these individuals to ensure accurate data collection. Overall, the study concluded that GPS data collection requires minimal training or instruction. In addition, it requires negligible reading and data-keying skills.

The reliability of data collection was very consistent in all studies. Two problems that affected the collection of data, and that were common in most of the literature, were loss of **lock** on satellites because of overhead obstructions and interruptions in signal reception because of system adjustments by the U.S. Department of Defense (DOD). The latter problem did not arise often, but DOD must maintain the accuracy of the system. When signals are interrupted or affected by this, data should be recollected.[12] Loss of signal reception because of overhead obstructions is normally caused by heavy tree canopy. Some studies have found that this causes a significant problem,[11] whereas others have found that this is not a significant problem depending on the density of the canopy and the speed at which the receiver is moving.[8,10] Tall buildings definitely limit signal reception and timing, thus severely affecting data collection and accuracy.[11]

GPS Case Studies

### Point Data for the SMS: Highway-Railroad Grade Crossings

The 27 public highway-railroad grade crossings in Albemarle County (15) and the City of Charlottesville (12) were registered as point data using the GPS receiver. The receiver was placed over the center of the grade crossing with respect to both the roadway and the railroad tracks. The center of the crossing was defined to be where the centerline of the track (for a single-track grade crossing) intersects the centerline of the roadway pavement (Figure 3). At locations where multiple tracks crossed a roadway, the receiver was placed over the approximate centerline of the two outermost rails and the centerline of the roadway pavement as shown in Figure 4.

Each crossing was recorded as a separate point feature, with a minimum of 120 data points recorded for each site. Each crossing was recorded as a separate rover file. The researchers used this technique to replicate the methods that would most likely be employed by the personnel responsible for conducting the grade crossing inventory in the field.

While registering the crossing location, researchers entered the crossing's DOT-AAR number (taken from tag mounted on post) into the receiver to aid in the identification of the crossing in the office. Researchers also photographed each approach to each crossing. Slides were produced to allow VTRC staff to scan the images into computer files for future use.

10
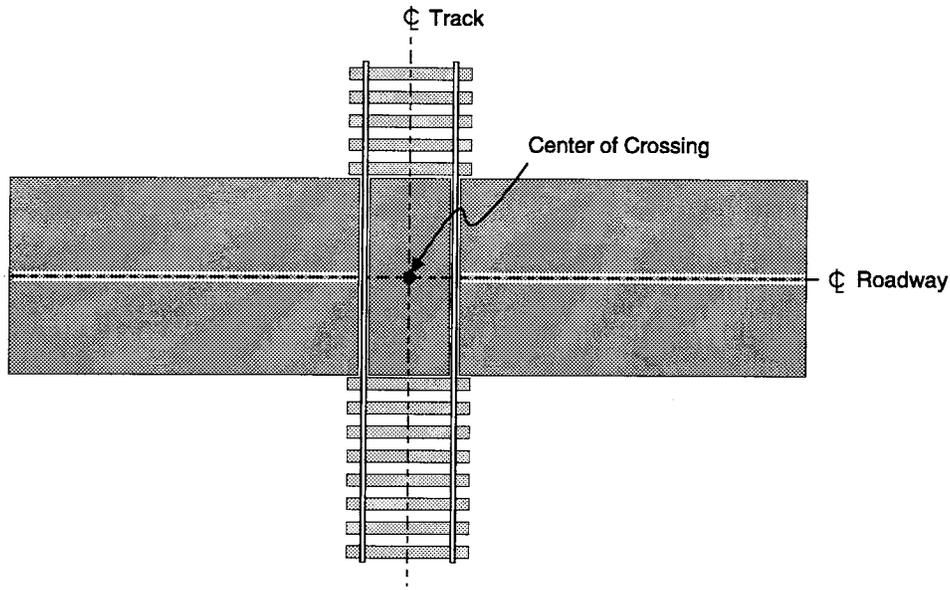
FIGURE 3. CENTER OF CROSSING DETERMINATION: SINGLE TRACK
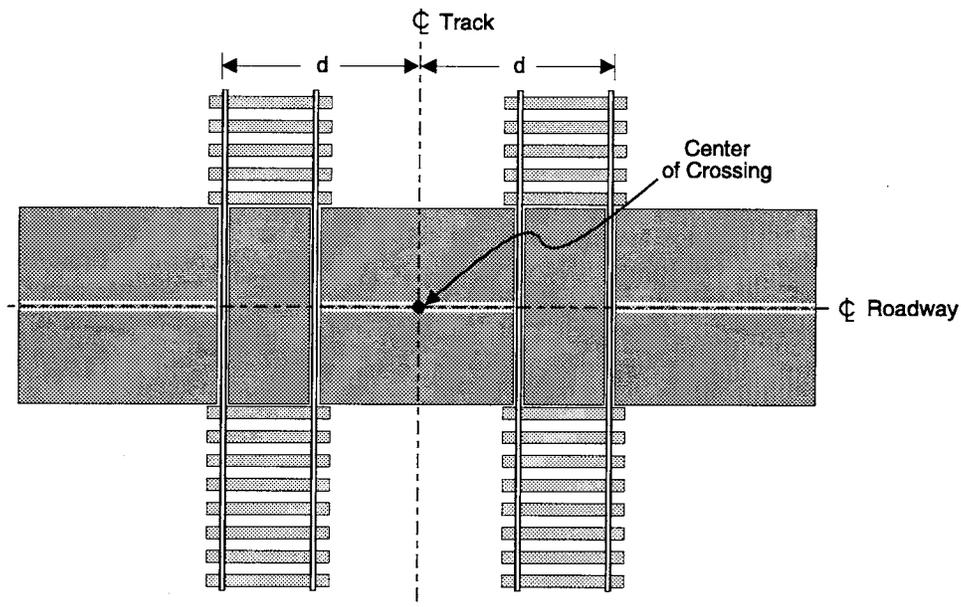
FIGURE 4. CENTER OF CROSSING DETERMINATION: MULTIPLE TRACK

The data collection took the researchers 12 hr for the 27 crossings. Approximately 15 min was spent at each crossing. The time required to register the location of the crossing and

input the DOT-AAR number into the receiver was only 4 min per crossing. The time spent to photograph each approach for one crossing was 2 min. The remainder of the time at each location was spent ensuring that the receivers were functioning properly, that they had lock on a sufficient number of satellites, and that they were collecting information properly. The time spent at each location represents approximately half the total time required to collect the data at all of the crossings. This discrepancy is primarily due to the grade crossings being located on secondary roads, usually on the outskirts of the county, requiring a significant amount of time to drive to each location.

Once in the office, the first step for the researchers was to download each rover file from the receiver to the PC. This process took only 30 sec to 1 min per file using the GPS software. Once the rover files were in the PC, the next step was to post process (differentially correct) them. To differentially correct the raw rover files, researchers needed to download base station files from a local bulletin board. Ten base station files had to be downloaded, representing each hour that a rover file was created. In a number of situations, several rover files were created in the same hour, and therefore only one base station file was required to correct these files. The time required to download the 10 base station files was 80 min, approximately 8 min per file.

Once the rover files were differentially corrected, they were exported to a format compatible with that of UNIX ARC/INFO® and imported into the GIS to build a point **coverage.** The process developed to complete this task is illustrated in Appendix A. Once the coverage was created, Figures 5 and 6 were developed. Figure 5 depicts the 27 public highway-railroad grade crossings and the railroad lines in Albemarle County and the City of Charlottesville. Figure 6 shows the 12 grade crossings collected using GPS in the City of Charlottesville.

Line Data for Operations and Maintenance: Adopt-a-Highway Program

The 45 AAH segments in Greene County were recorded as line data using the GPS receiver. Each segment was collected using the same method. The researchers began recording locations at one end of the segment and simultaneously entered the name of the segment (responsible party) and the applicable route number. Once the name and route number were entered, the researchers drove the segment maintaining the posted speed limit and remaining in the lane they started in, and stopped recording location information at the other end of the segment. The feature, AAH segments, was then closed, but the rover file remained open. This method was used because of the proximity of the AAH segments in this county. It also allowed the researchers to keep the receiver "seeing" the satellites, decreasing the amount of start-up time required before collecting the next AAH segment.

The collection of the AAH segments took 14 hr. The time spent collecting each segment varied, depending on the length of the segment, the terrain encountered, the availability of satellites, the prevailing speed limits, and other highway traffic. Therefore, no true average length of time was determined. The time required to register a segment's name and route number

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into the receiver also varied, depending on the length of the group's name responsible for the segment and the route number. Essentially, the time required to input an AAH segment was a maximum of 2 min.

Once in the office, the researchers' first step was to download each rover file from the receiver to the PC. This process took only 1 to 1.5 min per file using the GPS software. Once the rover files were in the PC, the next step was to post process (differentially correct) them. To differentially correct the raw rover files, researchers needed to download base station files from a local bulletin board. Nine base station files had to be downloaded, representing each hour the rover files collected data. The time required to download the nine base station files was 72 min, approximately 8 min per file.

Once the rover files were differentially corrected, they were exported to a format compatible with that of UNIX ARC/INFO® and imported into the GIS to build a line coverage. The process developed to complete this task is illustrated in Appendix B. Once the coverage was created, Figure 7 was developed, which depicts the 45 AAH segments and the county roads in Greene County.

Polygon Data for Compliance with the NEPA: Wetland Delineation

The boundary of the VDOT mitigation wetland site in Greensville County was collected as a single rover file. This wetland site itself occupies 30,403 m² of land. The receiver was taken to each flag marking the boundary. The flags were previously placed at the border of the wetland boundary by VDOT's Aquatic Ecology personnel. The file was opened at the first flag and allowed to receive signals for approximately 2 min (120 epochs). After the desired number of points had been collected at each flag, the file was paused and the receiver taken to the next flag. Care was taken not to overlook any hard-to-see flags, as this would result in a miscalculation of the boundary location. After each flag had been recorded (the perimeter of the wetland completely traversed) the rover file was closed. The collection of the boundary could have been completed in a manner similar to that of the line data previously described. However, since this particular wetland was previously marked by flags, it was determined that simply collecting a series of points at each flag and then averaging them would be most appropriate.

The single rover file was collected in approximately 3 hr. The file was then downloaded to a PC and post processed using base station files downloaded from a base station in Charlottesville. Again, the downloading of the base files took approximately 8 min for each hour of data needed. The corrected file was then grouped using the PFINDER software. In this grouping process, all of the points collected at a particular flag (approximately 120 points at each) were grouped or averaged to give a more accurate location value for the single flag. This procedure was followed for each of the 70 flag locations making up the file. Finally, the points were then joined as a single polygon, using the PC-based GPS software, representing the

boundary of the wetland and transferred to UNIX ARC/INFO® as outlined in Appendix C. The output of this procedure is shown in Figure 8.

Accuracy Determination

To measure the accuracy of the point, line, and polygon feature types collected, the researchers collected these data types using the process described in the Methods section.

Point Data

The point data was differentially corrected and imported into UNIX ARC/INFO® using commands similar to that of the highway-railroad grade crossing commands found in Appendix A. Table 2 depicts the difference in distance from the known HARN location and that of the GPS points. Figure 9 shows the HARN location and the 10 GPS derived points. As identified in Table 2 and in Figure 9, all but one of the corrected GPS points are accurate to within 1.5 m of the known location. The average distance from the known location is less than 1 m (0.92 m).

TABLE 2
ACCURACY OF GPS POINT DATA

Point Number	Distance from HARN (m)
1	0.86
2	0.85
3	1.23
4	1.08
5	1.64
6	1.05
7	0.90
8	0.46
9	0.64
10	0.45

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Line Data

The line data were differentially corrected and imported into UNIX ARC/INFO® using commands similar to those used in the AAH section and found in Appendix B. Table 3 depicts the actual test line length. As depicted in Table 3, only one of these lines has a percent difference greater than 2. The average length for the line segments collected using GPS is 45.68 m, which is only a 0.04-m difference from the test line segment.

TABLE 3
ACCURACY OF GPS LINE DATA

Line Number	Length (m)	% Difference
Test	45.72	0.00
1	45.92	0.45
2	46.18	1.01
3	45.67	0.11
4	45.26	1.00
5	44.63	2.38
6	45.02	1.53
7	45.97	0.55
8	46.06	0.75
9	45.92	0.44
10	46.14	0.92

Polygon Data

The polygon data were also differentially corrected and imported into UNIX ARC/INFO® using similar commands as the wetlands delineation commands in Appendix C. Table 4 depicts the actual test polygon area and each of the GPS-collected polygon areas and their corresponding percent differences. Figure 10 shows the polygons and their relationship to the HARN site and to each other. As identified in Table 4, two of the polygons had a percent difference greater than 2. The average area for the polygons collected using GPS was 914.25 m², which corresponds to a difference of only 1.01 percent of that of the test polygon.

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TABLE 4
ACCURACY OF GPS POLYGON DATA

Polygon Number	Area (m²)	% Difference
Test	905.13	0.00
1	913.01	0.87
2	904.27	0.10
3	906.10	0.11
4	923.68	2.05
5	924.20	2.11

DISCUSSION

Problems with Data Collection

As mentioned previously, problems will arise in the collection of data in areas with tall buildings. The researchers experienced this phenomenon, the urban canyon effect, while collecting data at a grade crossing in the City of Charlottesville. The crossing was in an area with tall buildings in three of the four surrounding quadrants (see Figure 11). The researchers were required to remain at this location for an additional 15 min until four satellites rotated to a point where they were visible to the receiver. The only problem this posed was that the time spent at this location was significantly increased.

While collecting the AAH segments, the researchers had only a few minor problems, none of them resulting from the use of the receiver. Because of the rural nature of Greene County, there were no signal disturbances caused by manmade obstructions. The first problem was physically locating the AAH segments. The map provided by the Charlottesville Residency was not current. It indicated numerous roadways as AAH segments that had no AAH signs and other roadways that were not AAH segments that had signs. While collecting the indicated AAH segments, researchers noted the other locations with AAH signs and collected the associated information. Although this problem was not significant, it did cause a problem in knowing the true number of AAH segments in Greene County as well as adding 4 hr to the data collection process.

Another problem associated with the collection of the AAH segments concerned the location of some of the segments. For instance, one segment was located on an unpaved single-lane mountain roadway. Figure 12 depicts the terrain and environment of the segment. This type of terrain will not adversely affect the accuracy of the data collected, but it will significantly add

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FIGURE 11. URBAN RAIL CROSSING WITH SATELLITE VISIBILITY OBSTRUCTION

FIGURE 12. ADOPT-A-HIGHWAY SEGMENT COLLECTED

to the time required to collect the data because the speed of the vehicle carrying the GPS receiver must be reduced.

Few problems were encountered during the collection of the wetland boundary. Most of the site was open, and the center of the area was ponded. This, coupled with the fact that the receiver was held stationary at each flag (the receiver was not in motion as it was in line data collection), resulted in at least four satellites being visible during the entire collection process. Obviously, depending on the time of year and location of the site, heavy tree canopy could come into play. However, other research[8,10] has indicated that signals can still be received even where heavy canopies exist.

Twice during the study, the receiver "saw" an adequate number of satellites to collect data but would not collect any information. This enigma usually continued for 20 min. Then, just as soon as the problem occurred, the receiver began receiving signals from the four visible satellites. The researchers assumed that this problem was due to the DOD restoring health to the satellites.

The time required to collect each feature type is given in Table 5. The majority of the time spent was in the initial data collection stage and during the creation of the ARC/INFO® coverage in the importing of DGPS in UNIX. The collection of point data was more time-consuming than the collection of line data. This was due primarily to the additional attribute data (photographs) collected for each point location. Collecting data using GPS allows for the simultaneous input of attribute data. Although this increases the time required to collect field data, it can potentially save time by significantly reducing the number of staff hours required to add attributes to the locational data back in the office.

As with any type of data collection, obstacles will be identified early in the process. Once they have been identified, the collection process will usually proceed smoothly. For the

TABLE 5
DATA COLLECTION AND TRANSFER TIME

Feature	Data Collection Time/Site	Download Rover File (min/file)	Download Base Station File (min/file)	Differential Correction (min/file)	Exporting DGPS (min)	Importing DGPS in UNIX (min)	Total Time (hr)
Point	15 min	0.5-1.0	8	1.0-1.5	10	20	14
Line	1-10 min	1.0-1.5	8	1.0-2.0	10	20	14
Polygon	5 hr	3.5-4.0	8	2.5-5.0	10	20	12

examples used in this study, the obstacles encountered did not pose a significant problem in the quality of the data collected. They only added to the time required to collect the data.

Data Conversion and Transfer

The conversion of PC-based GPS data to UNIX ARC/INFO® occupied a large amount of time for the researchers. Base station files were required to differentially correct the rover files collected. Since the researchers had to dial into a local bulletin board to download the base station files, a significant amount of time was spent for each file, nearly 8 min each. This is considered an excessive amount of time, especially when vast quantities of data are recorded over a long period of time. This limitation is due in large part to the rate at which the base station modem transmits data. Should this rate increase, the time required to download these files will decrease.

The software manuals provided for the GPS software and UNIX ARC/INFO® did not supply adequate instruction to transfer the corrected GPS files from the PC to the workstation. To complicate matters further, little instruction was provided concerning the process to combine attribute files from the PC to the workstation. A substantial amount of time, as shown in Table 5, was dedicated to the creation of Appendices A, B, and C to aid VDOT and other users in the conversion process to place the GPS files into a usable GIS coverage.

Since the test line and polygon coverages about the HARN location were collected in relatively small areas, the precision needed to be increased before generating these coverages. The researchers changed the default settings in ARC/INFO® from single, highest precision to double, highest precision before generating the coverage. This change increased the allowable number of decimal places the coverage was generating, thereby making it more precise. This change in the default settings does not always have to be made.

Data Accuracy

The accuracy values for the points collected at the HARN test site were assumed to be representative of any point data collected using similar procedures under similar conditions. Figure 13 depicts the anticipated maximum GPS error range of the collected grade crossings. Accuracy values stated by the manufacturer and those found in previous research were comparable to those found in this study.

Line value accuracies were better than originally anticipated. Because of the method of collection, the ends of each line segment were determined by recording only a single epoch (overcollection and averaging as were done for the point data were not performed). From previous research[10] and manufacturer statements,[6] the researchers assumed that error values

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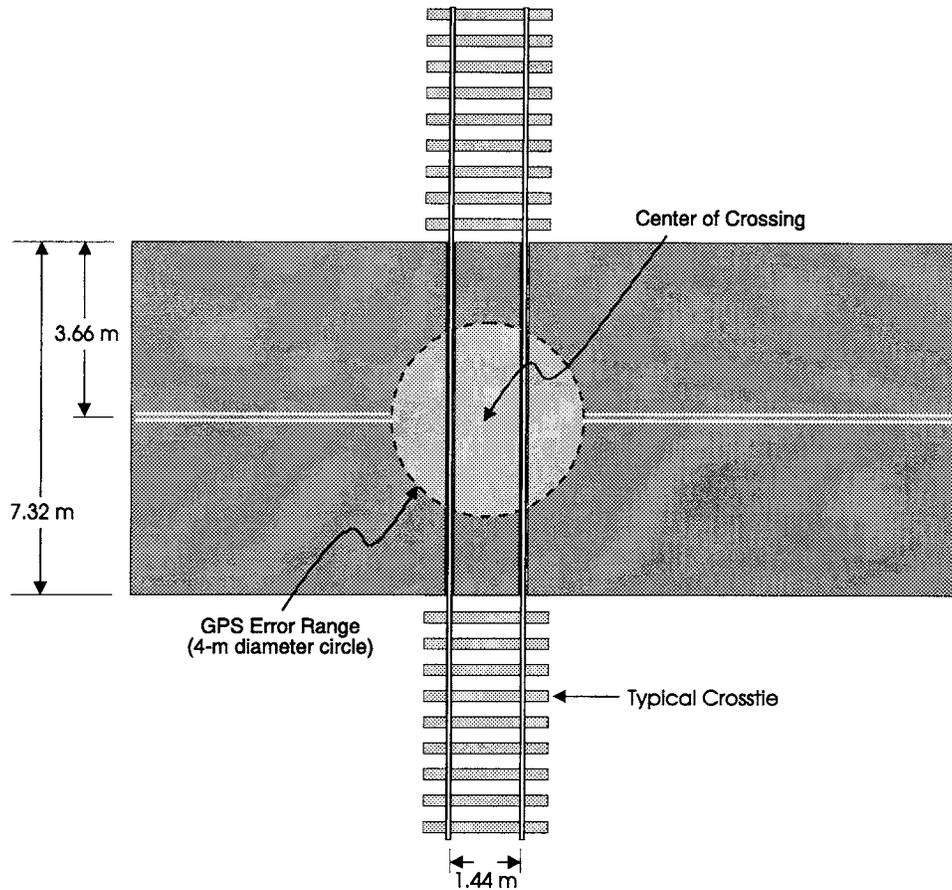
FIGURE 13. ANTICIPATED GPS ERROR RANGE FOR A TYPICAL GRADE CROSSING

would be between 6 and 10 m. The error values calculated were very close to those of the point data.

As shown in Table 4, the results of the area calculation from the GPS-derived polygon boundaries were quite accurate, with a maximum error of 2.11 percent. This percent difference is directly related to the size of the area. With a true total area of just over 900 m^2, the errors found were very small. However, to obtain accuracies comparable to those found here, data must be collected in a similar fashion and for polygons of at least this size. It would also be extremely difficult to obtain more accurate data by another method. If a digitizing or scanning method was used, the data source would have to be at a very large scale. A map at a 1:24,000 scale, for example, could potentially introduce errors of tens or even hundreds of meters.

The location calculation errors from the GPS-derived values were lower than could be obtained with most other methods of data collection. Most digitizing uses hard copy data at a scale that limits the accuracy of the digital output, regardless of the accuracy of the original source. When this hard copy data source is transferred to a digital source, additional error is

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introduced, depending on the scale of the source. For example, a 1:2400 aerial photograph will have inherent error because of the method of collection (distortion, pixel size, etc.). A 2.5-mm error when digitizing will result in a 6.1-m error being added to the original error of the hard copy source. GPS does not have errors associated with scale simply because the data are "digitized" at a 1:1 scale.

Evolution of GPS Technology

GPS technology continues to evolve. More sophisticated receivers are being developed that will reduce the errors associated with data collection. Even as these improvements are being made, the price for these enhanced receivers continues to decrease. Other enhancements include the ability to differentially correct data in real time. **Selective availability** (DOD's built-in degradation of GPS signals) may be eliminated in the near future. The culmination of these advancements would help make GPS feasible for more users in more applications. Conversely, however, since the entire system is owned and maintained by the DOD, end users have little or no control over the evolution of using GPS to collect data.

CONCLUSIONS

The findings of this and previous research are very encouraging for the use of GPS as a data collection method for GIS. Problems exist, but the availability and reliability of the system have increased dramatically over just the last few years.

Based on the findings of this study, the following can be concluded:

- *Locations on the earth's surface derived with GPS for any point, whether for a point, a point making up part of a line, or a point making up part of a polygon, were found to be within 2 m of their real-world location.*

- *Data collected by way of GPS are subject to system anomalies (such as an inadequate number of satellites visible to the receiver, DOD restoring health to the satellites, unusable satellite formation) that are not in the control of the data collector.* This may require the recollection of data during these periods.

- *Accuracies achieved by using mapping-grade GPS receivers are adequate for the collection of data for many of the priority applications related to planning and management in VDOT's GIS Strategic Plan.* This type of receiver will not provide accuracies acceptable for design purposes.

- *Differential GPS is a viable method for VDOT to use to collect spatially related data and their attributes to be used in a GIS.*

RECOMMENDATIONS

- *VDOT should identify priority data sets that could be collected with GPS for use with a GIS and begin to collect these data sets immediately.* These data sets can and should be stored until ready for incorporation into a GIS.

- *VDOT's Traffic Engineering Division should consider collecting each public highway-railroad grade crossing location using GPS and the procedures developed in this study for use in a GIS.*

- *All VDOT residencies should consider collecting Adopt-a-Highway segments for incorporation in an operations-level GIS following its eventual development.*

- *VDOT's Environmental Division should require that all newly created wetland mitigation sites be delineated using GPS for inclusion into the newly created wetland GIS application.*

- *Mapping-grade GPS receivers that allow for differential correction and the acceptance of attribute data should be used in order for VDOT to collect location data with accuracies similar to those achieved in this study and attribute data as collected in this study.*

- *A Phase II study should commence immediately following the issuance of this report.* This study should provide VDOT with two small GIS applications using the GPS data collected in this study. The study should depict the processes used and the problems encountered when developing a cradle-to-grave GIS.

- *A 1-day short course should be developed through the Virginia Transportation Technology Transfer Center to introduce field personnel and managers who are responsible for collecting information for use in a GIS to GPS, its uses, and how to import the information into a GIS.*

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APPENDIX A

**COMMANDS FOR CONVERTING GPS POINT DATA
TO A GIS POINT COVERAGE**

CONVERTING GPS POINT FILE WITH FEATURES
TO A UNIX ARC/INFO® POINT COVERAGE

This document describes the process used to move GPS files from the PFINDER software in a PC environment to an ARC/INFO® point coverage in a UNIX environment.

We collected all of the public highway-railroad crossings in Albemarle County and the City of Charlottesville. In addition to collecting the locations of these crossings, we collected the DOT-AAR number as an attribute to the crossing. The following steps provide you with a methodology to convert any GPS point files with features to an ARC/INFO® point coverage in a UNIX operating environment.

Navigating the PFINDER Software

The following are the settings to use when transferring GPS data from the PC to UNIX ARC/INFO®. From the **PFINDER** software on the PC, activate the *Output* pull down window and choose the *GIS* option. Under the *GIS* option, you can choose from a host of formats to which the GPS data can be output. Since you are using ARC/INFO® on a workstation, you want to select the first choice, *Arc/INFO (Workstation),* from the formats available.

GIS

Arc/INFO (Workstation)

After you have selected the type of GIS format the GPS data will be output in, you must select the Options menu. Under the Options menu, you will have several choices to make regarding the type of data that are being transformed and the manner in which they will be converted.

OPTIONS

Data Type

Under this subheading, you will be prompted to enter the type of data to output. You will need to make a selection between *GPS Positions Only* and *Features Only*. Since you are dealing with point information that has features, you should choose the **Features Only** option.

The next step is to apply additional filters to the data. First, choose the appropriate satellite constellation. You should always choose the **4 SVs or more** option since it provides the

highest possible accuracy. Next, choose from the three types of differential correction options. In order to obtain the highest possible accuracy, choose the **Corrected Only** option.

Attribute Type

This option under the menu allows you to specify the type of attribute information to output. Since you are interested in receiving the actual values for the attributes collected in the field, choose the **Attribute Value** option. (This option is also the default setting.) The next step is to apply offset to the features by choosing the **Apply Offset** command.

Number of Vertices

This option allows you to specify the number of vertices comprising a line feature to be output. Since this option is for line features, it does not apply; however, choose the **All** option anyway. (This is the default.)

Starting Feature ID

This option allows you to specify the starting ID number used to index individual features in the output file. Since you are starting the coverage from the beginning use **1**, which is also the default setting.

Elevation to Output

This option allows you to choose whether to include altitude values in the exported files. Since you are concerned only with two-dimensional point data, choose the **No Elevation** option.

Geodetic Datum

This option is used to select the datum to be used for the output and display of all the positions. It is important to know what Geodetic Datum is being used in your GIS. We have found that users in the Virginia Department of Transportation (VDOT) should use **NAD-83** at this option. (This datum will be changed in the ARC/INFO® projection stage. By choosing NAD-83 now, you will save a significant amount of time when attempting to convert projections.) In fact, Trimble recommends that users in North America use NAD-83.

Coordinate System

This option lets you select which coordinate system to use for the positions in the GIS file. You will find a wide range to select from; however, to decrease the complexity of transforming the GPS data to GIS, you should choose the **Latitude/Longitude/Altitude** option. This choice is also the default. Once you have selected this option, you will be prompted again to input the geodetic datum. In this case, you are using **NAD-83**.

Units

This option allows you to specify the units to be used in the GIS file. There are six settings under this subheading for you to specify, the first of which is the *Angle*. Under the *Angle* option, you will find four choices: degrees, minutes, seconds, and radians. The *degrees* selection outputs the coordinates and angles as decimal degrees; the *minutes* selection output the coordinates and angles as degrees and minutes; the *seconds* selection outputs the angle as degrees, minutes, and seconds; and the *radians* selection outputs the angle as radians. In the creation of this point coverage, you used the **Degrees** option. This option in fact is the recommended setting from Trimble.

The next setting for you to specify is the height. Since you specified earlier that you were not collecting altitude information, this option does not apply. However, you will still need to input a selection. Chose the **Ellipsoid** selection, which is the more accurate choice of the two.

The third setting to specify is the *Distance* units the GIS file uses. Since the GIS database VDOT is currently using is based on meters, you should select the **Meters** option.

The next selection is for you to specify is the *Decimal Accuracy* for use with the *Angle* selection chosen earlier under this subheading. Trimble recommends that when using the *Degrees* option, you should select an accuracy to 5 or 6 decimal places. This prevents problems if the GIS database cannot read the symbols for degrees, minutes, and seconds. For this coverage, you chose earlier that the *Angle* would convert to *Degrees* (decimal degrees); therefore, select an accuracy of **6** decimal places.

This option allows you to specify the units for velocity data recorded. Since the file does not contain any velocity data, you can ignore this setting. (Select the **Meters/Second** option for consistency.)

The next selection requires you to specify in which quadrant to output the coordinates. In this case, select the **NS/EW** option.

Position Date Format

This selection allows you to set the position date and time format. This option is not valid for ARC/INFO®; therefore, use the **Default** setting.

FILE

Input Files

This option lets you select which file(s) to convert to the GIS format. The file selected for conversion will normally have a *.COR extension unless it is a grouped file; then it will have a *.GRP extension. In this particular case, you will be converting the **RAIL.COR** file.

Output Path

This option allows you to specify where to place the newly created GIS output file. In this case, you want to place the file in the following directory: **C:\PFPRO\GISP1\RAILX**.

Direct Output To

This option allows you to specify whether the output is to be sent to a file or a file and printer. Since you are interested in using the data on a UNIX platform, you want the output in a **File** format.

Feature Output

This selection allows you to specify whether the output will be sent to one file or multiple files. Under this Subheading, there are three options to choose from. Since you are dealing with one feature in this example, highway-railroad grade crossings, you want to select the **One Feature Per File** option.

RUN

The next step is to execute the conversion. This can be accomplished by simply going to the *Run* menu and choosing the **Execute Conversion** option. This execution will create several files:

RAIL.INF   used to store information such as the output datum, projection, units, and other information related to the data used to create the output GIS file

RAIL_C2.PTS contains the position information for the RAIL point feature

RAIL_C2.PA   contains the attribute information for the RAIL point feature. It is associated with the RAIL_C2.PTS file. The two files are linked by their common user ID, as will be shown later.

Of the three files listed, only the RAIL_C2.PTS file and the RAIL_C2.PA file will need to be transferred to the UNIX ARC/INFO® to create the RAILX coverage.

SUMMARY

The following are the options chosen to output the GPS point data with its features to an ARC/INFO® UNIX coverage. The capitalized words in **bold** represent main menu heading, the upper and lower case words in ***bold and italic*** represent sub-menu headings, and the words or phrases underlined represent the options chosen under that specific heading.

GIS

Arc/INFO (Workstation)

OPTIONS

Data Type	Features Only
	4 SVs or more
	Corrected Only
Attribute Type	Attribute Value
	Apply Offset
Number of Vertices	All
Starting Feature ID	1
Elevation to Output	No Elevation
Geodetic Datum	NAD 83
Coordinate System	Lat/Long/Alt
	NAD 83
Units	Degrees
	Ellipsoid
	Meters
	6
	Meters/second
	NS/EW
Position Date Format	Default

Transferring Files to UNIX

The process used to transfer the two files from the PC to the SUN workstation is simple. First, copy the converted files from the PC's hard disk to a 3.5" floppy disk. Remove the floppy disk from the PC, and place the diskette into the disk drive on the workstation. The next step is to log in as yourself and start the *openwindows* program.

Once in *openwindows*, you can check the files on the floppy drive by clicking on the **Check For Floppy** choice under the *File* option in *File Manager*. Once the window appears that shows the files on the floppy, highlight the files you wish to copy and copy them to your directory. After the files have been placed in your directory, close out the floppy window and open a *Shell Tool* window. Next, make sure you are in your directory. If you are not, change directories now. Now, you will need to change the file's operating system from DOS to UNIX. This can be accomplished by issuing the following command string:

$ *dos2unix rail_c2.pts rail_c2.pts*

This command is simply telling the computer to convert the DOS *rail_c2.pts* file to a UNIX file also called *rail_c2.pts*. Now, re-issue the same command for the *rail_c2.pa* file. Once you have converted these two files to UNIX, you are ready to start the development of the RAILX coverage.

Creating the UNIX ARC/INFO® Point Coverage

You should still be in *Shell Tool*; if you are not, go there now. The next step is to make sure that you are in your directory. If you are not, change directories before proceeding. Once you have made sure that you are operating in your own directory, you will need to change your operating system from *kornshell* to *cshell* by issuing the following command:

$ *csh*

Now that you are in *cshell*, you can begin the host of ARC/INFO® programs by simply typing:

% *arc*

Once in *arc*, you will want to create a new coverage for the files transferred from the PC. To do this, you will first need to generate the coverage. In this case, you will be generating the coverage *rail*, which represents all of the public at-grade highway-railroad crossings in Albemarle County and the City of Charlottesville locations that were collected using the GPS receiver. You can create this coverage by issuing the following commands:

Arc: *generate rail*

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Once again, *rail* is the name of the coverage you are creating. Arc will prompt you to input the file that will be used to create the coverage and the type of coverage. In this case, you will be using the *rail_c2.pts* file to be the input file for the *rail* coverage and it will be a point coverage.

> GENERATE: *input rail_c2.pts*
> GENERATE: *point*
> GENERATE: *quit*

The next step is to build the coverage. This can be accomplished by simply typing:

Arc: **build rail point**

Once the coverage has been built, you will have to define the project that was used when you collected the data using the GPS receiver. In this case, you collected data using decimal degrees in North American Datum 1983 (NAD83). The following steps show the process used to define *rail*'s projections.

Arc: **projectdefine cover rail**

Project: **projection geographic**
Project: **units dd**
Project: **spheroid nad83**
Project: **parameters**

Since VDOT's basemap files are in a different projection, Lambert (Clarke 1866), you will have to change the coverage's projection to that of the basemaps' to run any type of analyses. The following steps will take you through the process:

Arc: **project cover rail railx**

Project: **output**
Project: **projection lambert**
Project: **units meters**
Project: **spheroid clarke1866**
Project: **parameters**

1st standard parallel	*37*	*0*	*0.000*
2nd standard parallel	*39*	*30*	*0.000*
central meridian	*-79*	*30*	*0.000*
latitude of projection's origin	*36*	*0*	*0.000*
false easting (meters)			*0.00000*
false northing (meters)			*0.00000*

Project: **end**

Please note that you created a new coverage, *railx*, with the Lambert projection, which is the same as the basemaps'. You will need to build this new coverage, *railx*, in order to apply the newly defined projection. This can be accomplished by issuing the following command:

Arc: **build railx point**

The *railx* coverage will be the coverage you will be using from now on to conduct analyses. The *rail* coverage can be deleted. Since you collected attribute information, you will need to attach that information to the coverage. The following steps describe how to import the data into the *railx* coverage.

Adding GPS-Collected Attributes in ASCII Format to Your Coverage

Now that the coverage has the correct projection, the next step is to join the coverage's PAT file with the ASCII file containing the GPS-collected attributes. You will need to go into the INFO program to define an ARC/INFO® recognizable file to enable you to attach the attributes collected in the field to the point coverage created above. *(NOTE: The INFO program is case sensitive; therefore, use all uppercase letters while in INFO.)*

Arc: *INFO*
ENTER USER NAME > *ARC*

Since you will be joining two files together and relating them using a common attribute, it is **imperative** that the relate item is defined identically to that of the identifier. That is, the ASCII file must have the attribute feature, *railx-id*, identical to that of the *railx* coverage's *railx-id* in the PAT file. To make sure that the identifier and the relate items are identical, first select the file that has the identifier in it and then show how the items are listed by typing the following:

ENTER COMMAND > *SELECT RAILX.PAT*

You have told the computer that you want to work with the *RAILX.PAT*, and it should have selected all of the items in the file.

ENTER COMMAND > *ITEMS*

This will describe the structure of the *RAILX.PAT*. Choose the item to which you want to join the ASCII file, and note the values in the template of the data file for that feature. Once you have the values for that particular feature, you can begin to define a new file that will be used to pull in the values in the ASCII file.

ENTER COMMAND > *DEFINE RAILX.DAT*

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After you have specified the name of the file, you will need to define the characteristics of its items. The identifier in the *railx* coverage is *railx-id*, and this is the name the relate item needs to be in your new data file, *railx.dat*. Once again, because this item will be used to join the two files, you must define the relate item in *railx.dat* exactly the same way it was defined in the *railx.pat*.

ITEM NAME	= *RAILX-ID*
ITEM WIDTH	= *4*
ITEM OUTPUT WIDTH	= *5*
ITEM TYPE	= *B*
ITEM NAME	= *DOT-AAR#*
ITEM WIDTH	= *7*
ITEM OUTPUT WIDTH	= *7*
ITEM TYPE	= *C*

Since you are adding only two items to your *railx.dat* file, enter a carriage return at the third prompt for an item name, as follows:

ITEM NAME > *<enter>*

Now that you have successfully defined the DAT file, you are ready to add to it the information contained in the ASCII file. Use the ADD FROM command (in INFO) to read the attribute values directly from the *rail_c2.pa* file. The ADD FROM command adds values contained in an ASCII text files to records in the currently selected INFO data file, in this case *railx.dat*. Note that when you use this command, you must enter the file's full pathname.

ENTER COMMAND > *ADD FROM /EXPORT/HOME/BRICH/RAIL_C2.PA*

Now quit from INFO and use the JOINITEM command in arc to join the *RAILX.DAT* data file with *RAILX.PAT*.

ENTER COMMAND > *Q STOP*

Arc: *joinitem railx.pat railx.dat railx.pat railx-id railx-id*

This command is simply telling ARC/INFO® to join the *railx.dat* file to the *railx.pat* file, rename it back to the *railx.pat*, and join the data file using the *railx-id* as the relate item as well as the name of the item after which the additional items will appear in the *railx.pat*.

You have now successfully imported a GPS coverage file and its attributes into an ARC/INFO® coverage. You can now produce maps and analyses.

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APPENDIX B

COMMANDS FOR CONVERTING GPS LINE DATA
TO A GIS LINE COVERAGE

CONVERTING GPS LIN FILES WITH FEATURES
TO A UNIX ARC/INFO® LINE COVERAGE

This document describes the process used to move GPS files from the PFINDER software in a PC environment to an ARC/INFO® line coverage in a UNIX environment.

We collected all of the Adopt-a-Highway segments in Greene County. In addition to collecting the locations of these segments, we collected the name of the group responsible for the segment and the route number on which the segment resides. The following steps provide you with a methodology to convert any GPS line files with features to an ARC/INFO® line coverage in a UNIX operating environment.

Navigating the PFINDER Software

The following are the settings to use when transferring GPS data from the PC to UNIX ARC/INFO®. From the **PFINDER** software located on the PC, activate the *Output* pull down window and choose the *GIS* option. Under the *GIS* option, you can choose from a host of formats to which the GPS data can be output. Since you are using ARC/INFO® on a workstation, you want to select the first choice, *ARC/INFO (Workstation),* from the formats available.

GIS

Arc/INFO (Workstation)

After you have selected the type of GIS format in which the GPS data will be output, you must select the Options menu. Under the Options menu, you will have several choices to make regarding the type of data that are being transformed and the manner in which they will be converted.

OPTIONS

Data Type

Under this subheading, you will be prompted to enter the type of data to output. You will need to make a selection between *GPS Positions Only* and *Features Only*. Since you are dealing with line information that contains features, you should choose the **Features Only** option.

The next step is to apply additional filters to the data. First, choose the appropriate satellite constellation. You should always choose the **4 SVs or more** option since it provides the

highest possible accuracy. Next, choose from the three types of differential correction options. To obtain the highest possible accuracy, choose the **Corrected Only** option.

Attribute Type

This option under the menu allows you to specify the type of attribute information to output. Since you are interested in receiving the actual values for the attributes collected in the field, choose the **Attribute Value** option. (This option is also the default setting.) The next step is to apply offset to the features by choosing the **Apply Offset** command.

Number of Vertices

This option allows you to specify the number of vertices comprising a line feature to be output. You have a choice of outputting all the positions comprising the line feature or limiting the number of positions to a set number. If the number of vertices is limited, this software will create multiple line entities where each entity has no more vertices than specified. However, for the GIS platform you are working with, there is no need to break down line segments. Therefore, choose the **All** option. (This is the default.)

Starting Feature ID

This option allows you to specify the starting ID number used to index individual features in the output file. Since you are starting the coverage from the beginning, select **1**, which is also the default setting.

Elevation to Output

This option allows you to choose whether to include altitude values in the exported files. Since you are concerned only with two dimensional point data, choose the **No Elevation** option.

Geodetic Datum

This option is used to select the datum to be used for the output and display of all the positions. It is important to know what geodetic datum is being used in your GIS. However, we found that users in the Virginia Department of Transportation (VDOT) should use **NAD-83** at this option. (This datum will be changed in the ARC/INFO® projection stage. By choosing NAD-83 now, you will save a significant amount of time when attempting to convert projections.) In fact, Trimble recommends that users in North America use NAD-83.

Coordinate System

This option lets you select which coordinate system to use for the positions in the GIS file. You will find a wide range to select from; however, to decrease the complexity of

transforming the GPS data to GIS you should choose the **Latitude/Longitude/Altitude** option. This choice is also the default. Once you have selected this option, you will be prompted again to input the geodetic datum. In this case, you are using **NAD-83**.

Units

This option allows you to specify the units to be used in the GIS file. There are six settings under this subheading for you to specify, the first of which is the *Angle*. Under the *Angle* option you will find four choices: degrees, minutes, seconds, and radians. The *degrees* selection outputs the coordinates and angles as decimal degrees; the *minutes* selection outputs the coordinates and angles as degrees and minutes; the *seconds* selection outputs the angle as degrees, minutes, and seconds; and the *radians* selection outputs the angle as radians. In the creation of this line coverage, you used the **Degrees** option. This option is the recommended setting from Trimble.

The next setting for you to specify is the height. Since you specified earlier that you were not collecting altitude information, this option does not apply. However, you will still need to input a selection. Chose the **Ellipsoid** selection, which is the more accurate choice of the two.

The third setting to specify is the *Distance* units that the GIS file use. Since the GIS database VDOT is currently using is based on meters, you should select the **Meters** option.

The next selection is for you to specify the *Decimal Accuracy* for use with the *Angle* selection chosen earlier under this subheading. Trimble recommends that when using the *Degrees* option, you select an accuracy to 5 or 6 decimal places. This prevents problems if the GIS database cannot read the symbols for degrees, minutes, and seconds. For this coverage, you had chosen earlier that the *Angle* would convert to *Degrees* (decimal degrees); therefore, select an accuracy of **6** decimal places.

This option allows you to specify the units for velocity data recorded. Since your file does not contain any velocity data, you can ignore this setting. (Select the **Meters/Second** option for consistency.)

The next selection requires you to specify which quadrant how to output the coordinates. In this case, select the **NS/EW** option.

Position Date Format

This selection allows you to set the position date and time format. Since this option is not valid for ARC/INFO®, use the **Default** setting.

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FILE

Input Files

This option lets you select which file(s) to convert to the GIS format. The file(s) selected for conversion will normally have a *.COR extension unless it is a grouped file; then it will have a *.GRP extension. In this particular case, you will be converting the four corrected rover files that comprise the Adopt-a-Highway segments in Greene County. These four files are **R110716A.COR, R110814A.COR, R110816A.COR**, and **R110915B.COR**.

Output Path

This option allows you to specify where to place the newly created GIS output file. In this case, you want to place the file in the following directory: **C:\PFPRO\GISP1\AAHSEG**.

Direct Output To

This option allows you to specify whether the output is to be sent to a file or a file and printer. Since you are interested in using the data on a UNIX platform, you want the output in a **File** format.

Feature Output

This selection allows you to specify whether the output will be sent to one file or multiple files. Under this subheading there are three options to choose from. Since you are dealing with one feature in this example, Adopt-a-Highway segments, you want to select the **One Feature Per File** option

RUN

The next step is to execute the conversion. This can be accomplished by simply going to the *Run* menu and choosing the **Execute Conversion** option. This execution will create several files, as follows:

R110*.INF	used to store information such as the output datum, projection, units, and other information related to the data used to create the output GIS file
ADOPT_2.GEN	contains the position information for the specific ADOPT line feature

ADOPT_2.AA   contains the attribute information for the ADOPT line feature. It is associated with the ADOPT_2.GEN file. The two files are linked by their common user ID, as will be shown later.

Of these three files, only the ADOPT_2.GEN and the ADOPT_2.AA files will need to be transferred to the UNIX ARC/INFO® to create the ADOPT coverage.

SUMMARY

The following are the options chosen to output the GPS line data with its features to an ARC/INFO® UNIX coverage. The capitalized words in **bold** represent main menu heading, the upper and lower case words in ***bold and italic*** represent sub-menu headings, and the words or phrases underlined represent the options chosen under that specific heading.

GIS

Arc/INFO (Workstation)

OPTIONS

Data Type	Features Only 4 SVs or more Corrected Only
Attribute Type	Attribute Value Apply Offset
Number of Vertices	All
Starting Feature ID	1
Elevation to Output	No Elevation
Geodetic Datum	NAD 83
Coordinate System	Lat/Long/Alt NAD 83
Units	Degrees Ellipsoid Meters 6 Meters/second NS/EW
Position Date Format	Default

Transferring Files to UNIX

The process used to transfer the two files from the PC to the SUN workstation is simple. First, copy the converted files from the PC's hard disk to a 3.5" floppy disk. Remove the floppy disk from the PC and place the diskette into the disk drive on the workstation. Next, log in as yourself and start the *openwindows* program.

Once in *openwindows*, check the files on the floppy drive by clicking on the **Check For Floppy** choice under the *File* option in *File Manager*. Once the window appears that shows the files on the floppy, highlight the files that you wish to copy and copy them to your directory. Once the files have been placed in your directory, close out the floppy window and open a *Shell Tool* window. Make sure you are in your directory. If you are not, change directories now.

Then, you will need to change the file's operating system from DOS to UNIX by issuing the following command string:

$ *dos2unix adopt_2.gen adopt_2.gen*

This command is simply telling the computer to convert the DOS *adopt_2.gen* file to a UNIX file, also called *adopt_2.gen*. Then, issue the same command for the *adopt_2.aa* file. Once you have converted the two files to UNIX, you are ready to start the development of the ADOPT coverage.

Creating the UNIX ARC/INFO® Line Coverage

You should still be in *Shell Tool*; if you are not, go there now. Next, make sure that you are in your directory before proceeding. If you are not, change directories before proceeding. Once you have made sure that you are operating in your own directory, you will need to change your operating system from *kornshell* to *cshell* by issuing the following command:

$ *csh*

Now that you are in *cshell*, you can begin the host of ARC/INFO® programs by simply typing:

% *arc*

Once in *arc*, you will want to create a new coverage for the files transferred from the PC. To do this, you will first need to generate the coverage. In this case, you will be generating the coverage *adopt_2* that represents all of the Adopt-a-Highway segments in Greene County that were collected using the GPS receiver. You can create this coverage by issuing the following command:

Arc: *generate adopt_2*

Once again, *adopt_2* is the name of the coverage you are creating. Arc will prompt you to input the file that will be used to create the coverage and the type of coverage. In this case, you will be using *adopt_2.gen* file to be the input file for the *adopt_2* coverage and it will be a line coverage.

GENERATE: *input adopt_2.gen*
GENERATE: *line*
GENERATE: *quit*

The next step is to build the coverage. This can be accomplished by simply typing:

Arc: *build adopt_2 line*

Once the coverage has been built, you will have to define the project that was used when you collected the data using the GPS receiver. In this case, you collected data using decimal degrees in North American Datum 1983 (NAD83). The following steps show the process used to define *adopt*'s projections:

Arc: *projectdefine cover adopt_2*

Project: *projection geographic*
Project: *units dd*
Project: *spheroid nad83*
Project: *parameters*

Since VDOT's basemap files are in a different projection, Lambert (Clarke 1866), you will have to change the coverage's projection to that of the basemap's to run any type of analyses. The following steps will take you through the process:

Arc: *project cover adopt_2 adopt*

Project: *output*
Project: *projection lambert*
Project: *units meters*
Project: *spheroid clarke1866*
Project: *parameters*

1st standard parallel	*37*	*0*	*0.000*
2nd standard parallel	*39*	*30*	*0.000*
central meridian	*-79*	*30*	*0.000*
latitude of projection's origin	*36*	*0*	*0.000*
false easting (meters)			*0.00000*
false northing (meters)			*0.00000*

Project: *end*

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Please note that you created a new coverage, *adopt*, with the Lambert projection, which is the same as the basemap's. You will need to build this new coverage, *adopt*, in order to apply the newly defined projection. This can be accomplished by issuing the following command:

Arc: **build adopt line**

The *adopt* coverage will be the coverage that you will be using from now on to conduct analyses. The *adopt_2* coverage can be deleted. Since you collected attribute information, you will need to attach that information to the coverage. The following steps describe how to import the data into the *adopt* coverage.

Adding GPS-Collected Attributes in ASCII Format to Your Coverage

Now that the coverage has the correct projection, the next step is to join the coverage's PAT file with the ASCII file containing the GPS-collected attributes. You will need to go into the INFO program to define an ARC/INFO® recognizable file to enable you to attach the attributes collected in the field to the point coverage created above. *(NOTE: The INFO program is case sensitive, so use all uppercase letters while in INFO.)*

Arc: *INFO*
ENTER USER NAME > *ARC*

Since you will be joining two files together and relating them using a common attribute, it is **imperative** that the relate item is defined identically with that of the identifier. That is, the ASCII file must have the attribute feature, *adopt-id*, identical with that of the *adopt* coverage's *adopt-id* in the AAT file. To make sure that the identifier and the relate items are identical, first select the file that has the identifier in it and then show how the items are listed by typing the following:

ENTER COMMAND > *SELECT ADOPT.AAT*

You have told the computer that you want to work with the *ADOPT.AAT*, and it should have selected all of the items in the file.

ENTER COMMAND > *ITEMS*

This will describe the structure of the *ADOPT.AAT*. Choose the item to which you want to join the ASCII file, and note the values in the template of the data file for that feature. Once you have the values for that particular feature, you can begin to define a new file that will be used to pull in the values in the ASCII file.

ENTER COMMAND > *DEFINE ADOPT.DAT*

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After you have specified the name of the file, you will need to define the characteristics of its items. The identifier in the *adopt* coverage is *adopt-id*, and this is the name of the relate item that needs to be in your new data file, *adopt.dat*. Once again, because this item will be used to join the two files, you must define the relate item in *adopt.dat* exactly the same way it was defined in the *adopt.aat*.

ITEM NAME	= *ADOPT-ID*
ITEM WIDTH	= *4*
ITEM OUTPUT WIDTH	= *5*
ITEM TYPE	= *B*

ITEM NAME	= *GROUP/INDIV_NAME*
ITEM WIDTH	= *20*
ITEM OUTPUT WIDTH	= *20*
ITEM TYPE	= *C*

ITEM NAME	= *ROUTE#*
ITEM WIDTH	= *5*
ITEM OUTPUT WIDTH	= *5*
ITEM TYPE	= *I*

Since you are adding only three items to your *adopt.dat* file, enter a carriage return at the fourth prompt for an item name, as follows:

ITEM NAME > *<enter>*

Now that you have successfully defined the DAT file, you are ready to add to it the information contained in the ASCII file. Use the ADD FROM command (in INFO) to read the attribute values directly from the *adopt_2.aa* file. The ADD FROM command adds values contained in an ASCII text files to records in the currently selected INFO data file, in this case *adopt.dat*. Note that when you use this command, you must enter the file's full pathname.

ENTER COMMAND > *ADD FROM /EXPORT/HOME/BRICH/ADOPT_2.AA*

Now quit from INFO and use the JOINITEM command in arc to join the *ADOPT.DAT* data file with *ADOPT.AAT*.

ENTER COMMAND > *Q STOP*

Arc: *joinitem adopt.aat adopt.dat adopt.aat adopt-id adopt-id*

This command is simply telling ARC/INFO® to join the *adopt.dat* file to the *adopt.aat* file, rename it back to the *adopt.aat*, and join the data file using the *adopt-id* as the relate item as well as the name of the item after which the additional items will appear in the *adopt.aat*.

You have now successfully imported a GPS line coverage file and its attributes into an ARC/INFO® coverage. You can now produce maps and analyses.

APPENDIX C

COMMANDS FOR CONVERTING GPS POLYGON DATA
TO A GIS POLYGON COVERAGE

CONVERTING GPS POLYGON FILES
TO A UNIX ARC/INFO® POLYGON COVERAGE

This document describes the process used to move GPS files from the PFINDER software in a PC environment to an ARC/INFO® line coverage in a UNIX environment.

We delineated a created wetland in Greensville County. The following steps provide you with a methodology to convert any GPS polygon files to an ARC/INFO® polygon coverage in a UNIX operating environment.

Navigating the PFINDER Software

The following are the settings to use when transferring GPS data from the PC to UNIX ARC/INFO®. From the **PFINDER** software located on the PC, activate the *Output* pull down window and choose the *GIS* option. Under the *GIS* option, you can choose from a host of formats to which the GPS data can be output. Since you are using ARC/INFO® on a workstation, select the first choice, *Arc/INFO (Workstation),* from the formats available.

GIS

Arc/INFO (Workstation)

After you have selected the type of GIS format in which the GPS data will be output, you must select the Options menu. Under the Options menu, you will have several choices to make regarding the type of data that are being transformed and the manner in which they will be converted.

OPTIONS

Data Type

Under this subheading, you will be prompted to enter the type of data to output. You will need to make a selection between *GPS Positions Only* and *Features Only*. Since the boundary was collected as a series of points, you should choose the **GPS Positions Only** option. It should be noted, however, that the boundary could have been collected as a single feature, in which case the **Features Only** option would be chosen.

The next step is to apply additional filters to the data. First, choose the appropriate satellite constellation. You should always choose the **4 SVs or more** option since it provides the

highest possible accuracy. Next, choose from the three types of differential correction options. In order to obtain the highest possible accuracy, choose the **Corrected Only** option.

Attribute Type

This option under the menu allows you to specify the type of attribute information to output. Since you are interested in receiving the actual values for the attributes that were collected in the field, choose the **Attribute Value** option. (This option is also the default setting.) The next step is to apply offset to the features by choosing the **Apply Offset** command.

Number of Vertices

This option allows you to specify the number of vertices comprising a line feature to be output. Since this option is for line features, it does not apply; however, choose the **All** option anyway. (This is the default.)

Starting Feature ID

This option allows you to specify the starting ID numberusedd to index individual features in the output file. Since you are starting the coverage from the beginning, use **1**, which is also the default setting.

Elevation to Output

This option allows you to choose whether to include altitude values in the exported files. Since you are concerned with only two-dimensional point data, choose the **No Elevation** option.

Geodetic Datum

This option is used to select the datum to be used for the output and display of all the positions. It is important to know what Geodetic Datum is being used in your GIS. We found that users in the Virginia Department of Transportation (VDOT) should use **NAD-83** at this option. (This datum will be changed in the ARC/INFO® projection stage. By choosing NAD-83 now, you will save a significant amount of time when attempting to convert projections.) In fact, Trimble recommends that users in North America use NAD-83.

Coordinate System

This option lets you select which coordinate system to use for the positions in the GIS file. You will find a wide range to select from; however, to decrease the complexity of transforming the GPS data to GIS you should choose the **Latitude/Longitude/Altitude** option. This choice is also the default. Once you have selected the option, you will be prompted again to input the geodetic datum. In this case, you are using **NAD-83**.

Units

This option allows you to specify the units to be used in the GIS file. There are six settings under this subheading for you to specify, the first of which is the *Angle*. Under the *Angle* option, you will find four choices: degrees, minutes, seconds, and radians. The *degrees* selection outputs the coordinates and angles as decimal degrees; the *minutes* selection output the coordinates and angles as degrees and minutes; the *seconds* selection outputs the angle as degrees, minutes, and seconds; and the *radians* selection outputs the angle as radians. In this case, use the **Degrees** option. This option in fact is the recommended setting from Trimble.

The next setting for you to specify is the height. Since you specified earlier that you were not collecting altitude information, this option does not apply. However, you will still need to input a selection. Chose the **Ellipsoid** selection, which is the more accurate choice of the two.

The third setting to specify is the *Distance* units that the GIS file use. Since the GIS database VDOT is currently using is based on meters, you should select the **Meters** option.

The next selection is for you to specify is the *Decimal Accuracy* for use with the *Angle* selection chosen earlier under this subheading. Trimble recommends that when using the *Degrees* option, you should select an accuracy to 5 or 6 decimal places. This prevents problems if the GIS database cannot read the symbols for degrees, minutes, and seconds. For this coverage, you choose earlier that the *Angle* would convert to *Degrees* (decimal degrees); therefore, select an accuracy of **6** decimal places.

This option allows you to specify the units for velocity data recorded. Since the file does not contain any velocity data, you can ignore this setting. (Select the **Meters/Second** option for consistency.)

The next selection requires you to specify in which quadrant to output the coordinates. In this case, select the **NS/EW** option.

Position Date Format

This selection allows you to set the position date and time format. This option is not valid for ARC/INFO®; therefore, use the **Default** setting.

FILE

Input Files

This option lets you select which file(s) to convert to the GIS format. The file(s) selected for conversion will normally have a *.COR extension unless it is a grouped file, then it will have

a *.GRP extension You will also need to join the points as a polygon after specifying the filenames.

Output Path

This option allows you to specify where to place the newly created GIS output file. In this case, you want to place the file in the following directory: **C:\PFPRO\GISP1\WETLAND\.**

Direct Output To

This option allows you to specify whether the output is to be sent to a file or a file and printer. Since you are interested in using the data on a UNIX platform, you want the output in a **File** format.

Feature Output

This selection allows you to specify whether the output will be sent to one file or multiple files. Under this subheading, there are three options to choose from. Since you are dealing with one feature in this example, a wetland boundary, you want to select the **One Feature Per File** option.

RUN

The next step is to execute the conversion. This can be accomplished by simply going to the *Run* menu and choosing the **Execute Conversion** option. This execution will create several files:

WETLAND.INF	used to store information such as the output datum, projection, units, and other information related to the data used to create the output GIS file
WETLAND.GEN	contains the position information for the specific WETLAND polygon feature.
WETLAND.PTS	contains the position information for the WETLAND point features making up the wetland boundary.

Of these three files, only the WETLAND.GEN file and the WETLAND.PTS file will need to be transferred to UNIX ARC/INFO® to create the WETLAND coverage.

SUMMARY

The following are the options chosen to output the GPS line data with its features to an ARC/INFO® UNIX coverage. The capitalized words in **bold** represent main menu heading, the upper and lower case words in ***bold and italic*** represent sub-menu headings, and the words or phrases underlined represent the options chosen under that specific heading.

GIS

Arc/INFO (Workstation)

OPTIONS

Data Type	GPS Positions Only
	4 SVs or more
	Corrected Only
Attribute Type	Attribute Value
	Apply Offset
Number of Vertices	All
Starting Feature ID	1
Elevation to Output	No Elevation
Geodetic Datum	NAD 83
Coordinate System	Lat/Long/Alt
	NAD 83
Units	Degrees
	Ellipsoid
	Meters
	6
	Meters/second
	NS/EW
Position Date Format	Default

Transferring Files to UNIX

The process used to transfer the two files from the PC to the SUN workstation is simple. First, copy the converted files from the PC's hard disk to a 3.5" floppy disk. Remove the floppy

disk from the PC, and place the diskette into the disk drive on the workstation. The next step is to log in as yourself and start the *openwindows* program. Once in *openwindows*, you can check the files on the floppy drive by clicking on the **Check For Floppy** choice under the *File* option in *File Manager*. Once the window appears that shows the files on the floppy, highlight the files you wish to copy and copy them to your directory. After the files have been placed in your directory, close out the floppy window and open a *Shell Tool* window. Next, make sure you are in your directory. If you are not, change directories now. Now, you will need to change the file's operating system from DOS to UNIX. This can be accomplished by issuing the following command string:

$ *dos2unix wetland.gen wetland.gen*

This command is simply telling the computer to convert the DOS *wetland.gen* file to a UNIX file also called *wetland.gen*. Once you have converted this file to UNIX, you are ready to start the development of the WETLAND coverage.

Creating the UNIX ARC/INFO® Line Coverage

You should still be in *Shell Tool*; if you are not, go there now. The next step is to make sure you are in your directory. If you are not, change directories before proceeding. Once you have made sure that you are operating in your own directory, you will need to change your operating system from *kornshell* to *cshell* by issuing the following:

$ *csh*

Now that you are in *cshell*, you can begin the host of ARC/INFO® programs by simply typing:

% *arc*

Once in *arc*, you will want to create a new coverage for the files transferred from the PC. To do this, you will first need to generate the coverage. In this case, you will be generating the coverage *wetland2,* which represents the perimeter of the created wetland. You can create this coverage by issuing the following commands:

Arc: *generate wetland2*

Once again, *wetland2* is the name of the coverage you are creating. Arc will then prompt you to input the file that will be used to create the coverage as well as the type of coverage. In this case, you will be using the *wetland.gen* file to be the input file for the *wetland2* coverage, and it will be a polygon coverage.

GENERATE: *input wetland.gen*
GENERATE: *polygon*
GENERATE: *quit*

The next step is to clean the coverage. This can be accomplished by simply typing:

Arc: *clean wetland2*

Once the coverage has been cleaned, you will have to define the project that was used when you collected the data using the GPS receiver. In this case, you collected data using decimal degrees in North American Datum 1983 (NAD83). The following steps show the process used to define *wetlands'* projections.

Arc: *projectdefine cover wetland2*

Project: *projection geographic*
Project: *units dd*
Project: *spheroid nad83*
Project: *parameters*

Since VDOT's basemap files are in a different projection, Lambert (Clarke 1866), you will have to change the coverage's projection to that of the basemap's to run any type of analyses. The following steps will take you through the process:

Arc: *project cover wetland2 wetland*

Project: *output*
Project: *projection lambert*
Project: *units meters*
Project: *spheroid clarke1866*
Project: *parameters*

1st standard parallel	*37*	*0*	*0.000*
2nd standard parallel	*39*	*30*	*0.000*
central meridian	*-79*	*30*	*0.000*
latitude of projection's origin	*36*	*0*	*0.000*
false easting (meters)			*0.00000*
false northing (meters)			*0.00000*

Project: *end*

Note that you created a new coverage, *wetland*, with the Lambert projection, which is the same as the basemap. You will need to clean this new coverage, *wetland*, in order to apply the newly defined projection. This can be accomplished by issuing the following command:

Arc: *clean wetland*

The *wetland* coverage will be the coverage you will be using from now on to conduct analyses. The *wetland2* coverage can be deleted. If attribute data for the polygon coverage had been collected, this information would be linked to the coverage as described in Appendices A and B.