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Supplementary Notes			

Abstract This report investigated the viability of using Global Positioning System (GPS) driven real-time data collection technology to capture appurtenance and line feature data for Alberta Transportation and Utilities Geographic Information System. The report examines different data collection methods, investigates real-time data collection and its various equipment components and recommends a solution. The proposed solution incorporates a mapping grade receiver manufactured by Trimble Navigation Limited with a differential correction service provided by Landstar. The data logger configurations, the accuracy of the recommended system, available technical support, training requirements and quality control methods are all discussed.

A field demonstration of the recommended system was performed on November 13, 1998 and November 20, 1998.

Key Words	**Distribution**
Global Positioning System (GPS) Data Logger Highway Inventory System Geographical Information System (GIS)	Unlimited **Project Coordinator** Stu Harper

ALBERTA TRANSPORTATION AND UTILITIES

GLOSSARY

GPS	Global Positioning System: A network of 24 satellites operated by the United States Department of Defense. Three-dimensional positions are determined by trilateration to satellites.
GIS	Geographical Information System
DGPS	Differential GPS
NAD83	North American Datum (1983)
σ	One Sigma Error: The standard deviation of an observation from its mean. The one sigma error indicates that for a Normal Distribution, 68% of the data is within the standard deviation.
PC	Personal Computer
PDOP	Position Dilution of Precision: A scalar expressing the quality of a GPS position as determined by satellite geometry. A low PDOP indicates good satellite geometry.
RTCM	Radio Technical Commission for Maritime Services. A commission that determines the data link for real-time differential services.
RTD	Real-time Differential GPS: Real-time corrected positions achieve meter leveler.
RTK	Real-time Kinematic GPS: Real-time corrected positions achieve centimeter level accuracies.
SNR	Signal to Noise Ratio: A measure of the strength of a satellite signal. The high SNRs indicate strong signals.
TM	Transverse Mercator map projection
WADGPS	Wide Area DGPS
WGS84	World Geodetic System (1984), the mathematical ellipsoid implemented in GPS.

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1. INTRODUCTION

Focus Surveys Ltd. has prepared the following report based on instruction from Alberta Transportation and Utilities (AT&U) Infrastructure System Support Section as described in the consulting services agreement dated September 30, 1998. The project is an investigation of the viability of utilizing GPS driven real-time data logger technology as a means of collecting location and attribute information in order to increase the efficiency of data collection for GIS applications.

AT&U has developed a GIS of highway appurtenances for inventory and maintenance purposes. Currently, AT&U implements a data collection system which consists of an electronic odometer measuring the mileage from a starting anchor point on a highway to the location of the appurtenance to be recorded. This system of data collection contains errors from variables such as temperature fluctuations, tire pressure and mechanical wear. The appurtenances are not given an exact location, merely a standard offset right or left of centerline at a given mileage. A more sophisticated method of data collection would reduce or eliminate errors in the current system and provide increased integrity, reliability and efficiency.

The purpose of the report is to investigate the viability of GPS driven data collection systems, qualify the accuracy of such systems and evaluate GIS compatibility issues.

2. SCOPE OF WORK

The project scope of work as defined by AT&U includes the following:

- Test and evaluate the use of GPS real-time data logger
- Evaluate data logger compatibility with AT&U NAD83 10TM coordinate system and Microstation Design File based maps
- Demonstrate the compatibility of downloading AT&U coordinate system and design files and pick menu
- Demonstrate collection of real-time GPS data of appurtenances and accurately display data on an electronic map
- Qualify the accuracy of the GPS based data using real time data collection methods
- Demonstrate the capabilities of attaching an attribute file to a specific appurtenance through the use of a pick type menu
- Demonstrate the capabilities to upload coordinates of a destination and navigate to that destination
- Answer general questions about the technology

The scope of work implies the need to research various hardware and software solutions for data collection and to formulate a recommendation on the products that best fit the application. Once the field system components have been determined, AT&U compatibility, expected accuracies, attribute capabilities and navigation capabilities can be evaluated.

3. METHODOLOGY

In order to provide answers to the items outlined in the scope of work, a project approach was devised. The methodology consisted of the following:

1. Research of hardware and software components and recommend a real-time data logger system.
2. Test the recommended system against published ASCM coordinates to determine absolute accuracies.
3. Ground truth the pilot project area (a portion of Highway 814) by surveying appurtenances with real-time kinematic GPS methods (capable of 0.1 to 0.01 meter accuracies).
4. Survey the pilot project area with the recommended system and compare to the ground truthing for relative accuracies.
5. Demonstrate the recommended system to the client.

4. LITERATURE REVIEW

The literature search consisted of industry periodicals, conference proceedings (Trimble Navigation Limited (Trimble) User Conference 1995 to 1997 and The University of Calgary Geomatics Engineering KIS97 Conference), manufacturer websites and product line pamphlets. The periodicals included GPS World, Point of Beginning, Professional Surveyor and Earth Observation Magazine, dating from 1995 to the present. The results of the search led to a short list of leaders in the GPS and laser ranging industries. Personal interviews, correspondence and product demonstrations were also conducted with manufacturer representatives and distributors.

5. GPS DATA COLLECTION SYSTEMS

When GPS positions are integrated with data dictionary capabilities, the resulting system becomes a useful tool to collect GIS data. GPS provides an all-weather, 24-hour, line of sight signal that is utilized for positioning information throughout the day when overhead obstructions do not exist. GPS positions can be derived in two modes; autonomous and corrected positions.

Autonomous GPS is a stand-alone solution capable of ±100-meter accuracies. The stand-alone solution utilizes one GPS receiver that computes positions. Environmental factors and selective availability (the intentional corruption of the GPS signal by the Department of Defense) degrade the positions. When the desired accuracy is ±100 meters, autonomous is a low cost solution for data collection and navigation. However, the requirements of this project are ±2-meter accuracies. Corrected positions are determined through applying a differential correction to the autonomous positions. This method is referred to as Differential GPS. Corrected positioning may be achieved by two different methods; corrected positions can be derived by post processing the data with PC based software or by applying corrections to the positions in real time.

5.1 Post Processing

Differential correcting (processing) the raw GPS data after collection has occurred produces post processed positions accurate to the specifications of this project. The positions are recorded in autonomous mode and are subsequently corrected for selective availability and atmospheric errors with corresponding base station data. Post processed positions do not rely on a radio link for broadcast corrections and may be statistically more confident than real-time positions. Post-processed methods do not confirm position integrity in the field. Post processing requires large amounts of raw GPS data to be stored, transferred and processed, which is a labour intensive method of determining corrected positions.

5.2 Real-time Positions

As an alternative to post processing, corrected positions may be determined using real-time techniques. Real-time correction services broadcast the differential correction to the user's receiver allowing for corrected positions to be calculated in real-time. By collecting corrected positions, office labour, data storage requirements and data manipulation time are reduced. (Corrected positions are stored rather than raw GPS data.) Real-time positions provide a finished product in the field, which is beneficial for quality control, data viewing and navigation purposes. Interpolation and extrapolation errors in the correction model and other minimal system biases may produce less accurate final positions. Positions may be derived utilizing real-time kinematic and real-time differential methods.

RTK techniques provide a limited range, accurate position, ideally suited for local site surveys. RTK utilizes a base station on a known position established by the user, that broadcasts the correction via radio modems. RTK requires two GPS receivers and radios. The solution is capable of determining positions at centimeter level accuracies, as the correction is applied to the code and carrier phase observables. RTK is currently limited by the inability of the system to achieve confident centimeter level accuracies beyond a range of 10 kilometers from the base station. RTK equipment and methods are costly and require the rover receiver to maintain lock with a minimum of five satellites at all times. RTK carrier phase wide area corrections may become available in the future and could be considered as an upgrade route.

The RTD solution is not limited by range. The solution applies one WADGPS correction broadcast by a third party (C-Band geostationary satellite vehicle, FM radio frequency or cellular based correction) and one receiver. RTD does not require the rover receiver to maintain lock with satellites, making the solution more flexible than RTK. The real-time differential method applies a correction to the GPS code observable only and is capable of sub-meter accuracies. RTD is less accurate than RTK methods, and is dependent on an external correction service.

The accuracy specifications requested by AT&U require that corrected positions be implemented in a GPS data collection system. Corrected positions can be derived by post processing and real-time methods. Post-processed positions are accurate, but require additional data manipulation. RTK is an accurate real-time solution, but is costly and does not provide a wide area solution. Presently, the RTD solution provides a more practical solution for a provincial wide data collection application.

6. THE ADVANTAGES OF GPS DRIVEN DATA COLLECTION

Electronic data collection poses many advantages over manual field logging methods. Errors associated with recording, transcribing and inputting observational data and feature codes can be virtually eliminated. Time can be saved in the field and during the data input phase through automated processing of the information, and quality assurance checks can be built into the system to promote data integrity. GPS driven data collection provides a dynamic inventory management program.

The integration of GPS and GIS yields benefits and advantages over traditional data capture methods. The field systems consist of a portable GPS receiver connected to a rugged pen-based computer operating data collection software. The office component involves data processing software that can verify and convert the field data to the desired output format. Data collection and manipulation times can be significantly reduced as the process can be almost entirely automated from field to finish.

DGPS corrections are received from differential services and utilized to correct the real-time positions of the roving field unit. The location of the rover and the data feature being collected are displayed against a moving background map, providing immediate feedback to the field crew pertaining to the relative placement and accuracy of the appurtenance ties. GPS positioning can achieve very repeatable accuracies, allowing AT&U staff and contractors to easily relocate previously surveyed appurtenances.

The background maps can represent parcel boundaries, alignment routes and maps, previously tied appurtenances, or other geographically referenced objects or boundaries. The field staff is able to monitor current conditions affecting the accuracy of the GPS observations, and confirm coordinate systems and projections of both the background maps and the collection system.

The captured data is symbolized to represent the feature, thus enabling real-time verification of the data coding process, and minimizing guesswork of interpreting field notes. The data collection process includes input of attributes associated with the features. The attributes are entered from a pick list of values, providing consistent GIS-ready data.

The field survey data is electronically downloaded, analyzed, cleansed, and converted into a format ready to be ported into a GIS system. The result is an efficient flow of data from the field to the central data repository.

7. EQUIPMENT REVIEW

The GPS real-time data collection system consists of several components integrated to capture location and attribute data. AT&U system specifications allowed the determination of a "short-list" of component providers. Tendency towards a single source solution allowed even more refinement to this short-list.

7.1 GPS EQUIPMENT

The GPS receiver component of a data collection system determines the position of the roving field unit. The short list of GPS mapping grade receiver manufacturers consists of the following four companies:

- Trimble
- Ashtech
- Novatel
- Sokkia

The following spreadsheet evaluates the four GPS manufacturers' mapping grade receivers.

Table 1: Receiver Comparison - Mapping Grade Solutions

	Trimble Pro XRS	Ashtech Reliance	Novatel Gismo	Sokkia GIR 1000
Frequency (S/D)	L1	L1	L1	L1
Channels	12	12	12	12
Max. # Satellites Tracked	12	12	12	12
Track and Output Code Phase	Yes	Yes	Yes	Yes
Track and Output Carrier Phase	Yes	Yes	Yes	Yes
Real Time DGPS	Yes	Yes	Yes	Yes
Operating Temperature (Celsius)	-30 to 65	-20 to 55	-20 to 50	-20 to 55
Accuracy in meters (2drms)				
Real Time	<1.0	<1.0	0.20-0.40	<1.0
Post Processed	0.01-0.1	0.75	0.02+2ppm	0.01+1ppm
Antenna				
GPS	Included	Included	Included	Included
DGPS	Integrated	External	External	External
Weight in lbs	1.68	1.5	2.6	6
Size (H"xW"xD")	1.95x3.7x6.5	4.4x2x7.8	2.4x5.1x9.6	1.9x3.7x6.5
Post Processing				
In Field Capabilities	Yes	Yes	Yes	Yes
IBM Compatible	Yes	Yes	Yes	Yes
Price				
Backpack Solution*	20403.00	16140.00	14725.00	17902.00
PenBased Computer Solution**	17001.00	19735.00***	N/A	N/A
Post Processing Software	Included	Included	3875.00	Included
Typical System Costs	17001.00	19735.00 + DGPS	18600.00 + DGPS	17902.00 + DGPS

*Includes GPS Receiver, antenna, software, hand held data logger and accessories

**Does not include cost of PenBased Computer

***Includes Condor PenMap software with GPS interface

DGPS = costs of DGPS antenna and receiver and does not include DGPS subscription

(1998). Receiver Survey. GPS World. January, p46-53. (1998). POB 1998 GPS Equipment&Software Suvey.Point Of Beginning August, p38-48. (1997) GPS Listing. Professional Surveyor. July/August, p33-48.

The four GPS receivers have similar capabilities and none of the manufacturers' receiver/firmware combinations provided a significantly better positional solution when differential correction methods were applied. Manufacturers all claim sub-meter accuracies under specific optimal conditions. The functionality of the Trimble Pro XRS receiver should be noted because Trimble offers an integrated DGPS receiver and antenna option, eliminating the need to purchase an external antenna/receiver package.

7.2 SOFTWARE

The GPS receiver is one component of the data collection system. The preceding section highlighted the hardware (receivers) and the firmware (programs imbedded in the receiver which compute positions and statistical information about the positions). Software is also important to the final solution. Software incorporates the positions collected by the receiver with a graphical representation of the data, attribute information and import/export capabilities. Trimble and Condor Earth Technologies, Inc. provide mature software for GPS real-time mapping applications. Trimble's mapping grade software product line includes Pathfinder Office™, Asset Surveyor™, and Aspen™ software. Pathfinder Office allows the user to perform mission planning, create data dictionaries, edit data, perform post processing differential corrections and import/export data to GIS platforms. Trimble's field data collection software includes Asset Surveyor and Aspen. Aspen is pen-based computer software and Asset Surveyor is software for hand held data loggers. The functionality of the two is comparable. Condor Earth Technologies, Inc. manufactures PenMap for Windows. PenMap is field data collection and editing software, with export capabilities that allow the user to create data dictionaries, capture and edit data and export the data to a GIS platform directly from the pen-based computer.

The AT&U requirement for a moving background map limited the software choices to Aspen and PenMap. Both software packages are compatible with offset sensors, support moving background maps and can export to Microstation compatible formats. Table 2 highlights the differences in the two software choices.

Table 2: Apsen and PenMap Comparison		
	PenMap	Aspen
Customization of Software		
Required	Yes	No
Possible	Yes	Yes
Data Dictionary Editing	In field	In office
Mission Planning Software Included	No	Yes
GPS Quality Control Indicators	Open another window	Always Displayed

(1998) www.trimble .com. (1998) www.condorearth.com.

7.3 DGPS Services

In order to obtain 1 to 2 meter accuracies from a GPS system in real-time, a differential correction must be applied. As mentioned previously, selective availability causes the coordinates derived from autonomous GPS to have a random error of up to ± 100 meters. Differential GPS (DGPS) is a service that provides real-time corrections to eliminate the error.

A number of DGPS services exist in North America, however the need for accuracy of 1 to 2 meters and province wide coverage reduced the list of service providers to four. Omnistar, Landstar, and Global Surveyor all calculate a correction and uplink that correction to a C-Band geostationary satellite vehicle, which then broadcasts the correction. Similar to the GPS signal, geostationary-based corrections must have a direct line of sight to the user's receiver. Pleiades is a service that broadcasts corrections over a cellular network. All four WADGPS services provide corrections over wide areas.

Landstar is a worldwide service that is based on modeling corrections from a network of base stations. The service claims sub-meter accuracies, depending on the quality of the GPS receiver and environmental conditions. The network "models all GPS error sources in the area under consideration (e.g. North America)."[1] The network of base stations includes 19 stations in the

[1] Fotopoulos, G., Cannon, M.E., Bogle, A., and Johnston, G. (1998) *Testing LandStar's Performance Under Operational Conditions*. Proceedings of the Institute of Navigation National Technical Meeting, Long Beach, California. 207-215.

continental United States and four stations in Canada, one situated in Edmonton. A minimum of four stations is incorporated in the modeled correction.

Omnistar is a worldwide DGPS service that implements a network of base stations. Omnistar also claims sub-meter accuracies for its differential correction under optimal conditions. Omnistar employs 11 reference sites, all of which are situated in the United States. The service incorporates "several reference sites"[2] in order to model the environmental and selective availability errors for a wide area differential correction.

Global Surveyor is a service initiated by the British Columbia government via the Geographic Data BC Department and covers British Columbia and Alberta. Global Surveyor broadcasts corrections relative to two base stations at Terrace and Williams Lake, British Columbia. The service specifications are one to 10 meter accuracies, dependent upon the quality of the user's GPS receiver and environmental conditions.

Finally, Pleiades is a correction service based in Alberta that implements a cellular digital packet data (CDPD) modem to broadcast a correction. The cellular network coverage is presently not province wide in Alberta, but the correction service may be considered as an option in areas where satellite-based DGPS signals are not attainable.

Table 3 is a comparison of the four DGPS services investigated. The functionality and costs of the services are highlighted in the table.

[2] www.omnistar.com/techdesc.html

Table 3: Differential GPS Service Comparison				
	Omnistar	Landstar	Global Surveyor	Pleiades
Coverage	Provincial wide	Provincial wide	Provincial wide	Cellular Phone coverage
Claimed Accuracy	Sub-meter	Sub-meter	1-10 meter	1-2 meter
Broadcast Datum	NAD83	WGS84(G873)	NAD83	NAD83
Costs				
Initial Activation	N/A	N/A	N/A	160.00
Activation per year	1248.00	1248.00	2100.00	4230.00**
Antenna and Receiver	5565.00*	7495.00*	Rental Included	1076.00 (modem)

*includes one year subscription fee

** inlcudes Telus Mobility Plan 2500 and Telus Additional Kb Charges for CDPD

www.omnistar.com . (1998) www.racal-landstar.com. (1998) www.env.gov.ba.ca/gdbc/gsn/glblsuvy/tec_desc.html. (1998) info@pleiadesdata.com.

7.4 OFFSET SENSORS

In order to determine the coordinates of features such as signs, lights and guardrails from a remote location, a sensor must be integrated in the measuring system to determine the vector from the GPS unit to the feature. Laser rangers, with distance and azimuth determination capabilities provide real-time vector measurements. Laser Atlanta and Laser Technologies are manufacturers whose products met the needs of the application. Testing of the laser rangers found that the distance measurement had repeatable results, but the azimuth determination was limited due to the internal electronic compass being susceptible to magnetic anomalies from surrounding metal objects. In order to determine the offset, both vector observables are required.

The Advantage, from Laser Atlanta utilizes an internal compass. The laser can be calibrated in the vehicle, but is sensitive to any significant movement within the vehicle. Expected accuracies for the azimuth determination are ± 5°. The accuracy of the azimuth determination, assuming a maximum offset distance of 10 meters, is sub-meter.

The Impulse, manufactured by Laser Technologies Inc., is a lower cost laser capable of distance ranging only. An external, vehicle mounted compass and perpendicular offsets can provide the azimuth component of the vector. When the vehicle is at right angles to the appurtenance, the azimuth can be input manually as the perpendicular of the vehicle heading. The accuracy of this configuration is comparable with the Advantage laser.

7.5 Pen-based Computer

A pen-based computer was selected for the operating system to support PC based software. Pen-based computers facilitate data entry without the need for a keyboard, are compact, robust and designed for field applications. The Fujitsu Stylistic 1200 computer satisfied the needs of the pilot project.

8. EQUIPMENT RECOMMENDATIONS

After a cursory review of data collection equipment, the recommendations concentrate on products manufactured by one particular vendor. Comprehensive testing and equipment performance comparisons were beyond the scope of the project and available funding. Recommendations were based on the Equipment Review and the personal experience of the authors, in addition to AT&U requirements. AT&U specified a need for a total package solution that would benefit the user in a number of ways. When one manufacturer supplies a majority of the components of a system, compatibility issues are reduced and technical support is provided by a single source. In addition to a total package solution, interoperability of the components, ease of use, availability of technical support, and cost were the criteria the components were tested against.

Compatibility of hardware and software, data dictionary sharing, interchangeable configurations and the ability to upgrade played an important role in recommending a data collection system. Trimble products provide an environment that satisfies the interoperability criteria. Trimble maintains compatibility throughout its product lines and therefore components are interchangeable. This is significant for AT&U as the receiver component can be substituted with a lower cost receiver for navigation purposes or with a survey grade receiver if the accuracy requirement were to increase. Trimble supports a platform that maintains the data collection foundation while varying the receiver, field collection software or operating system and therefore the data collection system is not affected by such modifications. As developments in technology continue, equipment can be easily supplemented when a single manufacturer solution is implemented, which reduces the time lapses between upgrades associated with products that claim compatibility with other manufacturers.

Ease of use implies that equipment is easy to assemble, the operation of equipment is intuitive and the learning curve is short. Trimble's product line complies with the ease of use criteria. The equipment components are minimized and assembly is comprehensive. The software is menu driven and includes on-line help that is easy to understand. The menu driven platforms of the software are efficient and do not impede productivity (ease of use should not offset the efficiency of the data collection system.)

The availability and quality of technical support is an important factor when choosing equipment. Vendor support should be easily accessible from a number of sources. Trimble Navigation is an industry leader in surveying and mapping GPS equipment and provides customer support through their Technical Assistance Center, Internet sites as well as authorized distributors. Trimble dealers provide the necessary hardware needed to support the offset sensors and provide technical assistance.

Finally, cost was the last criteria the equipment components were tested against. The integrated GPS and DGPS receiver and antenna eliminate the need to buy external DGPS equipment, which reduces the cost and complexity of the data collection system.

The Pathfinder Office/Aspen and Pathfinder Office/Asset Surveyor software package provided by Trimble supplies the user with the functionality necessary to design and implement data collection. While PenMap supports field editing of the data dictionary and direct export to GIS platforms, the additional functionality of Pathfinder Office/Aspen provides the user with greater versatility. Mission planning, post processing differential correction capabilities and data editing are features that the PenMap software lacks. The compatibility of Trimble also allows the user to alternate between Aspen and Asset Surveyor without major alterations. This is beneficial when changing the data collection system from a pen-based computer configuration to a backpack configuration. Condor Earth Technologies, Inc. does not offer a software product comparable to Asset Surveyor.

The integrated Pro XRS system receives DGPS corrections from Landstar or Omnistar DGPS providers. Global Surveyor and Pleiades require an external antenna and receiver to accept broadcast corrections. Landstar is the recommended DGPS service due to the compatibility with all GPS systems, reliability, coverage of the broadcast signal, and cost of the service as illustrated in Table 3. In addition, accuracy of the service meets or exceeds Omnistar, Global Surveyor and Pleiades, as Figure 5 demonstrates.

The external components of the Pro XRS system are the offset sensor and pen-based computer utilized when operating Aspen software. Both are fully compatible with the Pro XRS. As mentioned previously, one of two different methods may be implemented to capture offset vector information. The Pro XRS is compatible with Laser Atlanta and Laser Technology products and the choice of equipment is dependent on field procedure preference. The Advantage laser requires calibration and minimal movement within the vehicle and the Impulse requires perpendicular offset procedures to be practiced. The accuracies are comparable for both methods.

9. DATA LOGGER CONFIGURATIONS

9.1 DATA COLLECTOR WITH LAPTOP, PICK LISTS AND MAP

The data collector with laptop, pick list and map configuration consists of Trimble's Pro XRS coupled with a pen-based computer running Aspen software and an offset laser. The versatility and robustness of the pen-based computer and the Pro XRS allows this system to be truck mounted or transformed into a backpack system and removed from the vehicle. When the system is truck mounted, the laser is connected and used to determine the offset vector to the appurtenance relative to the GPS antenna.

9.2 Data Collector with Pick Lists, but no Map

The Pro XRS solution is based on the Asset Surveyor Software that operates on a TSC1 hand held data logger manufactured by Trimble and included in the Pro XRS with Asset Surveyor system. Asset Surveyor supports the same data dictionary and data logging functionality as Aspen. The Asset Surveyor software does not support background maps and does not have the same data viewing capabilities. The Pro XRS backpack solution is based on the Asset Surveyor Software that operates on a TSC1. The Pro XRS backpack solution can be truck mounted and utilize a laser for offset measurements since the system can be transformed from a backpack into a truck mounted configuration with ease.

9.3 Truck Mounted Equipment with Extension Cable

The need for truck mounted equipment with an extension cable for collecting offset appurtenances is eliminated by the ability of the Pro XRS to easily adapt between the truck mounted and backpack solutions.

9.4 Low Cost Device to Navigate to a Previously Collected Location

Low cost receivers or "hand-held" receivers can be used to navigate to a previously collected location. The receiver must be capable of uploading appurtenance coordinates and may utilize a DGPS correction service to increase the navigation accuracy. To maintain system continuity and interoperability throughout, the GeoExplorer, manufactured by Trimble, would be one recommended hand-held receiver. The receiver is capable of navigating to within $\pm$ 100 meters in autonomous mode and can achieve $\pm$ 2 - 5 meter accuracy levels with a differential correction. The Geo Explorer supports the same data dictionary as Aspen and Asset Surveyor, but has limited data collection capabilities.

10. EVALUATION OF MEASUREMENT ACCURACY

10.1 SUSTAINABLE ACCURACY LEVELS

Information regarding the achievable accuracies of positions is important when incorporating data into a GIS, as the quality of data affects the integrity of the GIS fabric. An evaluation of the measurement accuracy is also necessary to determine whether the recommended data collection system provides improved achievable accuracies over the existing electronic odometer method. The Pro XRS was tested for absolute and relative accuracies to determine the measurement accuracies.

10.1.1 Receiver Accuracy

The absolute accuracy of the receiver was determined by testing the Trimble Pro XRS, with Landstar's DGPS real-time corrections, against the published coordinates of Alberta Survey Control Markers (ASCMs). The ASCMs are second order, integrated survey stations established by the provincial government.

The differences between measured coordinates (real-time differential and post processed) and published coordinates are illustrated in Figures 1 to 3. The real-time accuracies are one meter for the northing and easting coordinates and one to two meters for the height coordinate. The receiver accuracy is based upon operational conditions that take into account satellite geometry, signal noise, multipath and signal delays caused by various atmospheric conditions. As Figures 1 to 3 demonstrate, sub-meter accuracies are possible under optimal conditions. The height coordinate is generally less accurate due to satellite geometry.

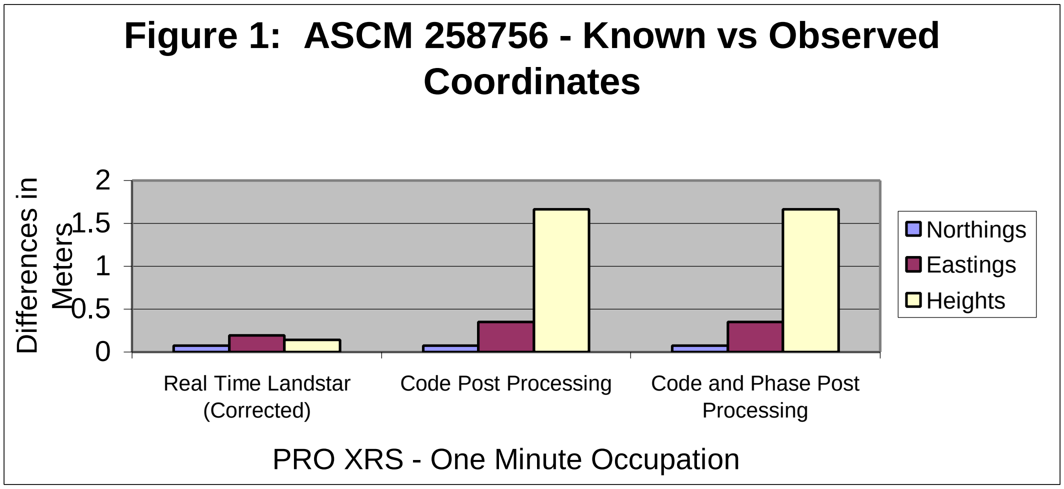


Figure 1: ASCM 258756 - Known vs Observed Coordinates
Differences in Meters
2
1.5
1
0.5
0
Real Time Landstar (Corrected)
Code Post Processing
Code and Phase Post Processing
PRO XRS - One Minute Occupation
Northings
Eastings
Heights

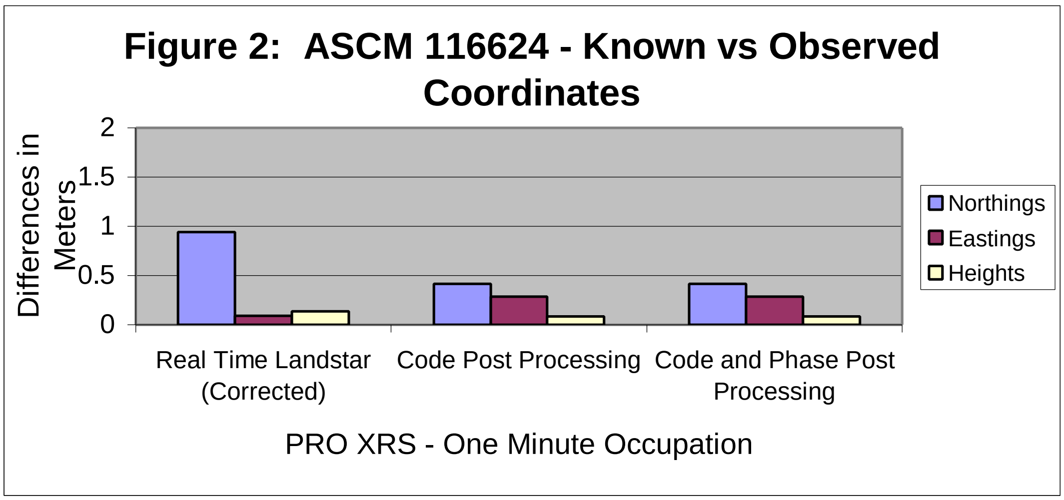


Figure 2: ASCM 116624 - Known vs Observed Coordinates
Differences in Meters
2
1.5
1
0.5
0
Real Time Landstar (Corrected)
Code Post Processing
Code and Phase Post Processing
PRO XRS - One Minute Occupation
Northings
Eastings
Heights

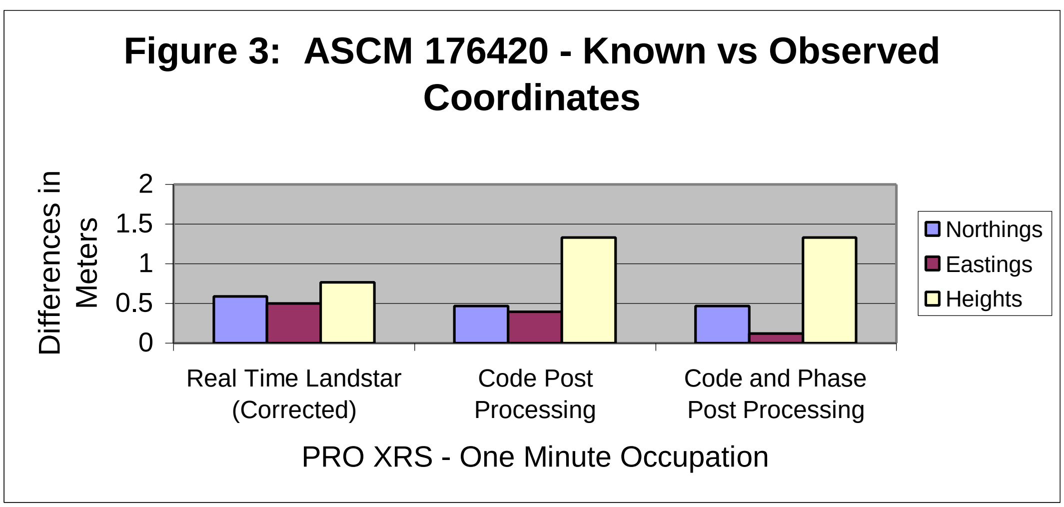
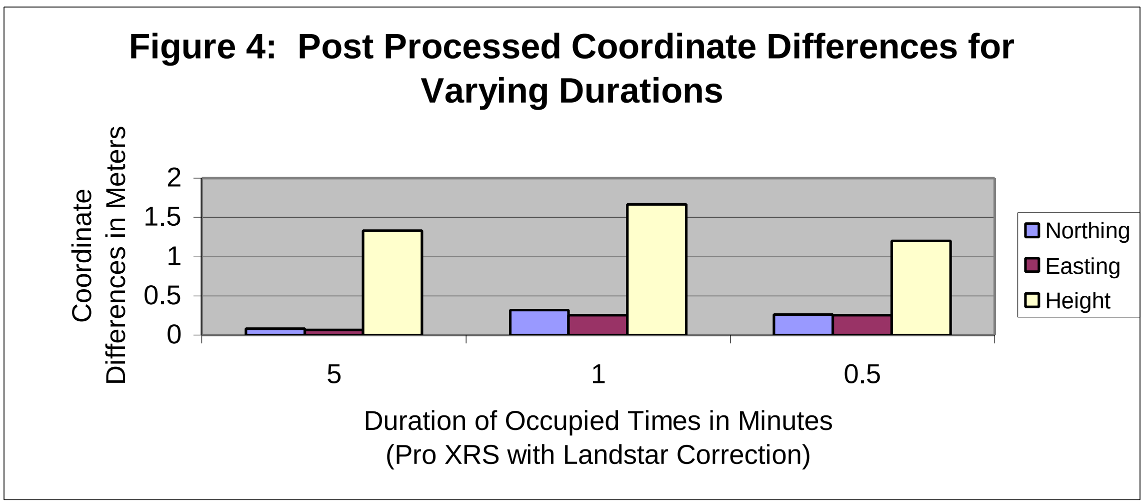


Figure 3: ASCM 176420 - Known vs Observed Coordinates
Differences in Meters
2
1.5
1
0.5
0
Real Time Landstar (Corrected)
Code Post Processing
Code and Phase Post Processing
PRO XRS - One Minute Occupation
Northings
Eastings
Heights

The real-time differential solution may be less accurate than post processing since the correction is modeled for a wide area and not a specific locale. However, in Figures 1 through 3, the post processing positions are not always more accurate than the real-time differential positions. The real-time data was logged at one-second intervals and the post-processed data was available at five-second intervals. The larger volume of data for the real-time differential can lead to a better positional accuracy. The one-minute occupation time for the data simulates the amount of time needed to collect location and attribute data of an appurtenance in the field. When features are occupied for a longer duration, the accuracy of the code and carrier phase post processed position, as compared to known coordinates, improves as seen in Figure 4.



Landstar's correction is based on the WGS84 (g873) datum, which differs from NAD83 Canada by one to two meters. Landstar claims sub-meter accuracies for its correction, which is achievable once the one to two-meter shift in Landstar's reference datum is considered. This shift[3] was calculated by applying a datum transformation to the observations and is corrected for in the above figures. It is important to apply the datum shift to real-time differential data when applying a differential correction from Landstar.

[3] Fotopoulos, G. and Cannon, M.E. 1998. Relationship Between NAD83 and WGS 84. The Department of Geomatics Engineering. University of Calgary.

10.1.2. DGPS ACCURACY

The accuracy of the DGPS services was also evaluated. The Trimble Pro XRS receiver was used for the four DGPS services investigated in order to eliminate any receiver-based variables. A station with known coordinates, Focus Base, was used to compare the measured real-time coordinates derived from the different DGPS services. Coordinate values for Focus Base were derived from second order ASCM monuments and would be considered to be high third order quality.

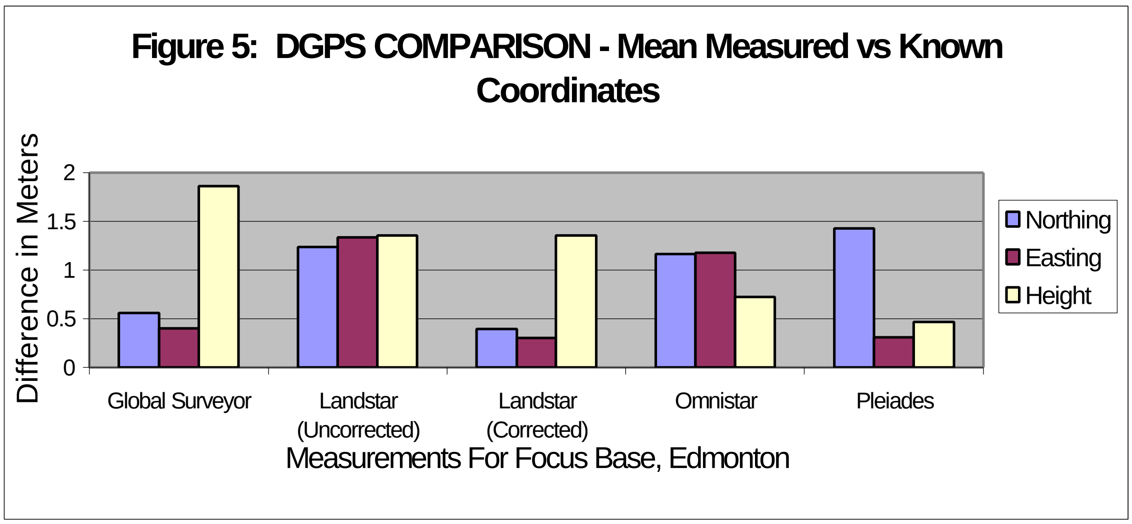


Figure 5 indicates that the differences are sub-meter for measured mean coordinates of Focus Base from the known 2D coordinates. The means are derived from a minimum of 1500 one-second epochs. Landstar, once corrected for the datum shift, displays sub-meter accuracies and is the most accurate correction service.

10.1.3. OFFSET ACCURACY

The Advantage laser from Laser Atlanta was tested to determine the accuracy of the distance ranging capabilities only. The azimuth determination accuracy does not meet the requirements of this project. The distance determination is accurate to the decimeter level (0.1 meters), which is consistent with manufacturer specifications of $\pm$ 0.15 meters. The largest error arises from the azimuth determination. Both magnetic anomalies and pointing errors, depending on the choice of laser, can be reduced when care is taken when performing offset ties and by limiting the range to 10 meters. Offset accuracies are estimated at 1.0 meters.

10.2 Relative Accuracy

The relative accuracy of the system was tested by comparing the results of the Pro XRS survey with the data collected during the ground truthing of the pilot project site. The ground truthing consisted of surveying the appurtenances, culverts and pavement messages on Highway 814 south of Beaumont with RTK methods. The absolute accuracy of the ground truthing data was sub-decimeter as several second order ASCMs were incorporated into the survey to provide accuracy checks. The results of the comparison are shown below:

Table 4: Coordinate Differences - RTK vs RTD

	Northing	Easting	Height	Radial Distance (2D)
Maximum	1.6	3.0	38.6	3.4
Minimum	-1.3	-1.9	-2.1	0.2
St. Dev.	0.6	0.8	6.8	0.6
Average	0.3	-0.5	1.5	1.0

Appendix A contains the full analysis of the comparison of the RTK and real-time differential coordinates of the appurtenances surveyed for the pilot project. The average difference between the ground truthing and the recommended data collection system coordinates is sub-meter. The maximum and minimum differences indicate anomalies in the data that could be a result of poor geometry, multipath, poor azimuth determination or blunders. The average 2D difference is 1.0 meters and the standard deviation is 0.6 meters making over 68% of the data fall within 1.6 meters of the actual coordinates. The measured coordinates and their differences can be found in Appendix A.

10.3 Repeatability of Measurements

Under normal operating conditions, the positions of the appurtenances collected with the recommended system are repeatable to ± 2 meters. The GPS signal is consistent and maintained by the Department of Defense. The DGPS signal is modeled from a network of base stations and is consistent as well. Operator error is the only component of the data collection system that is inconsistent. However, excluding gross errors, the operator error is minimal.

The total systematic error of the recommended system is the square root of the sum of the squares of the individual component errors.

ESTIMATED ERRORS

GPS Receiver Errors (a)	= 1.00 m
DGPS Correction Errors (b)	= 1.00 m
Laser Ranger Errors (c)	= 0.15 m
Offset Azimuth Errors (d)	= 1.00 m
Operator Errors (e)	= 0.50 m

$$\textbf{Error} = (a^2 + b^2 + c^2 + d^2 + e^2)^{1/2}$$

Total Estimated One s Error = 1.8 meters

Estimated Errors based on Manufacturer Specifications.
Trimble Pro XRS "sub-meter" accuracies. www.trimble.com
Landstar Correction "one meter or less." www.racal-landstar.com
Offset Azimuth based on expected accuracies of ±5° in azimuth and range of no greater than 10 meters.

The total estimated one sigma error of 1.8 meters is consistent with the results of the pilot project. The comparison of the data collected with the recommended system and the ground truthing showed the real-time differential positions being accurate within 1.6 meters of the actual positions.

10.4 DATA COLLECTION CONSTRAINTS

GPS is a 24-hour, all weather navigation system, but is susceptible to the dynamic satellite constellation and environmental conditions. 3D Real-time positions are derived by trilateration from a recommended minimum of five satellite vehicles, and are therefore dependent on the geometry of the satellites. The PDOP (Positional Dilution of Precision) is one indicator of the geometry of the satellites at any given time. The greater the PDOP, the less accurate a given point will be. It is important then, to plan data collection missions when the PDOP is less than 6 (factory default) and the number of satellite vehicles is greater than five. QuickPlan (pre-planning software included with Pathfinder Office and Aspen) allows the user to pre-plan missions and determine when the geometry is favorable.

Other constraints that limit the GPS signal are environmental conditions. The data collection system should not be expected to operate in areas where the GPS signal could be obstructed by heavy foliage. The GPS signal may be corrupted by multipath, which occurs when a signal is reflected off surrounding material, causing a delayed and erroneous signal. Multipath is dependent on the environmental surroundings of the GPS antenna and can be minimized with proper antenna placement. The configuration of the truck-mounted system minimizes the multipath error, and operators should avoid reflective mediums and obstructions when employing the backpack configuration.

Differential GPS methods generally reduce the effects of ionospheric delay (signal errors caused when the GPS signal is delayed as it passes through the upper layer of the atmosphere.) Ionospheric delay can corrupt GPS positions by up to seven meters when left uncorrected.[4] The GPS Differential correction reduces ionospheric delay since generally the same error is experienced at the rover and base stations simultaneously. However, the cyclic behavior of the ionosphere creates periods of high activity when the ionospheric delay at the two stations is not highly correlated. The average length of an ionospheric cycle is 11 years, and the year 2002 is the estimated peak of the current cycle. Solar storms and sunspots caused by high ionospheric activity are possible sources of error, with distortions already being observed.

4 M.E. Cannon. 1998. Satellite Positioning Lecture Notes. The Department of Geomatics Engineering. The University of Calgary. 4-2.

11. TYPICAL VENDOR TECHNICAL SUPPORT

11.1 VENDOR SUPPORT

Trimble manufactures the majority of the recommended GPS data collection system components. Trimble provides customer support through Technical Assistance Centers, accessible by toll-free telephone lines, the Internet and e-mail, providing 24-hour assistance. Trimble also maintains a Web page and an FTP site with the most recent developments and improvements to their software and hardware firmware available for downloading and upgrading.

Cansel Survey Equipment is the distributor for Trimble products in Canada. Cansel also provides laser-ranging systems manufactured by Laser Technology. Cansel maintains a network of technical resources and facilities to support products they sell. The staff includes knowledgeable sales representatives, repair technicians, full-time technical support, and Certified Trimble Trainers. New product demonstrations and training seminars are held regularly at Cansel offices, allowing the user to stay current with changes in products and technology. Cansel also maintains a large inventory of rental equipment and replacement parts to supplement or address the user's needs. In Alberta, toll-free technical support can be obtained by telephone or e-mail.

Butler Survey Supplies (Edmonton) Ltd. is the distributor for Laser Atlanta Advantage Laser, Ashtech GPS products and PenMap software. The staff includes knowledgeable sales representatives, repair technicians and technical support personnel. Product demonstrations and information seminars are provided for users that are interested in product and technology advances. Equipment rentals and replacement parts are readily available to meet the needs of the user. Butler Survey Supplies provides a toll-free telephone line for contacting technical support staff.

Appendix B contains further information on how to contact specific vendors for technical information.

11.2 IN-HOUSE SUPPORT

The agency should have a support system for ensuring the data capture project is proceeding in an efficient and reliable manner. The technical support staff would be responsible for:

- quality assurance of the data capture process
- assessing and scheduling staff training
- equipment upgrading, including software, hardware and firmware
- field equipment maintenance procedures and repairs

A working comprehension of the different phases of the project (without detailed knowledge) would assist the personnel in providing answers to problems that may arise. The staff should have a good understanding of the concepts of GPS, the data collection process and be aware of potential problems in order to provide solutions to problems as they are encountered.

12. TRAINING REQUIREMENTS

The training needs of all personnel involved in the data collection process, whether in the field, office, or in a supervisory capacity, are similar. All members of the project team should be aware of the various stages of GIS data capture in order for the project to be successful. Personnel will receive specific training in their respective roles, and gain basic knowledge of the entire operation, including equipment, concepts, procedures, and expected outcomes. The training sessions listed below address the training requirements of all personnel involved in the project, and in some cases, can be tailored to individual needs.

Trimble provides a variety of product training options. Training could be any one of the following: attending a course at a training center (held regularly in Calgary & Edmonton); hiring a Certified Trainer to provide on-site courses, and custom tailor the topic and duration to your needs and application; or purchasing a Pathfinder Office computer based training CD-ROM.

The recommended courses for this application are **Introduction to Pro XRS with Asset Surveyor** or **Introduction to Pro XRS with ASPEN** for field staff, office data handlers, and project supervisors. Instruction on the principles of GPS, the aspects of field data collection, and data processing with Pathfinder Office are covered. The courses include the following topics:

- GIS/GPS data collection
- Mission planning
- Data Dictionary creation & editing
- Hands-on field exercises
- Data processing and analysis
- GIS data export and import

The **Pathfinder Office Computer Based Training CD-ROM** is an interactive, self-paced course that combines simulations, animation, and voice explanation. This teaching tool is suitable for beginner and intermediate users, and can serve as a platform for continued learning, or as a reference to supplement an experienced users' knowledge.

After the initial introduction to the concepts and equipment, field crews should commence supervised data collection missions, capturing real data in the field. Many issues may appear during the field collection sessions which may not be anticipated in simulated or classroom training sessions, particularly in regards to the interpretation of appurtenance attributes or tie point locations. With practice and experience, the field crews can learn to adjust to and remedy most situations that may arise. Production gains and increased efficiency can be expected, as field crews become more comfortable with the data collection process.

13. QUALITY CONTROL METHODOLOGY FOR AN ONGOING DATA COLLECTION PROGRAM

Successful results can be achieved when implementing a data collection system by following a consistent set of guidelines that includes planning, equipment preparation, data collection, data processing, editing and quality analysis. Quality control is a methodology implemented from the initial planning stage to the final data exportation to the GIS.

13.1 PROJECT PLANNING

The specific requirements of the data collection session and the general conditions of the data collection sites may be known prior to mobilizing to the field. These field conditions should be considered and appropriate action taken to minimize situations that degrade the quality of the data. For example, the topography of the area can be ascertained from local maps, and may point out areas where observations would be less than optimal, such as valleys and mountainous terrain. Factors to consider during the planning stages include:

- Resource allocation – number of crews and equipment selection.
- Logistics – access routes and scheduling.
- Collection Method – one or two way directional pickup.
- Site Constraints – obstructions effecting GPS and DGPS signals.
- GPS coverage – satellite visibility and geometry.
- GPS corrections – real-time or post processed.
- GPS occupation times – dependent on quality indicators and project requirements.
- Overlapping coverage – preferable to data gaps.
- Data Dictionary - specific site requirements.
- Feature Tie-in Location – operator consistency.
- Safety Concerns – weather conditions, width of roads, emergency response.

13.2 Equipment Preparation

The GPS/GIS equipment should be checked prior to commencing a data collection session:

- Power supplies – batteries, adapters, inverters, and back-ups.
- Cables – GPS, controller, computer, charging and their conditions.
- GPS Antenna - maximize reception and minimize multipath.
- Data Dictionary – current version is uploaded to controller or computer.
- External Sensors – complete and operational; placement considered.

The configuration settings on the data collector should be confirmed to ensure the accuracy and integrity of the data. These settings include:

- Logging Intervals
- Position Mode
- Elevation Mask
- Position Filter Masks (SNR & PDOP)
- DGPS communication parameters
- GPS observables recording modes

The datum and coordinate system display modes should be set to match those of the background maps and GIS database.

13.3 DATA COLLECTION

During data collection, several procedures should be followed for quality assurance purposes. The Aspen and Asset Surveyor provide quality control measures in the software. The project manager allows the user to configure the parameters of data collection. At this point, the coordinate system and background maps should be confirmed. AT&U uses a 10° Transverse Mercator projection on the NAD83 datum for its GIS base maps in DGN format. For the purpose of the project, the base map has been converted to the DXF format because presently the DGN format is not supported in Aspen.

The next step involves starting Aspen, which automatically powers-on the Pro XRS receiver, initiating satellite tracking and reception of DGPS signals. The status line in Aspen and Asset Surveyor indicates the number of satellite vehicles (#SV), the PDOP and the presence of the DGPS correction (RTCM). RTCM SC-104 is a data format developed to broadcast differential corrections. As previously mentioned, the number of satellites must be greater than 5, the PDOP must be lower than 6 and the RTCM icon must be present to assure the quality of the data. The status line also provides messages regarding any changes in the operating conditions of the system.

When the data collection system configurations have been confirmed and the status line indicators are positive, then data capture can begin. The integrity of the system can be confirmed during data collection through a number of methods. The operators could tie in control points with known coordinates such as ASCMs or previously collected features as a method to verify the GPS data. Also, the collected features can be compared to the background map in order to confirm data and identify blunders.

Analysis of the statistical output of a feature can indicate when post processing of the positional data is necessary to acquire the required accuracy. Situations occur when the DGPS correction is unavailable or the quality of the measurement is poor and therefore quality control methods would incorporate post processing to enhance data. Both positional and attribute data can be edited in order to assure the quality of data that is transferred into the GIS. For a comprehensive description of the GPS data collection field procedures, see Appendix C.

13.4 DATA PROCESSING

Upon completion of the field segment of a data capture session, the information needs to be downloaded, verified, possibly post processed, and exported to the GIS database. The office routine should include the following elements:

13.4.1 Data Transfer

The data collection file is transferred from the field computer or data logger to an office computer via a communication cable, infrared link, or PCMCIA card. A backup procedure should be instituted at this point to allow recovery from inadvertent editing, data loss or file corruption.

13.4.2 Quality Analysis

The GPS positions collected in the field for each point feature are averaged into one position. The status and statistics associated with the observations are displayed in the dialog box, and can be exported to an external file. The status indicates the mode used to calculate the position, such as: real-time kinematic; real-time differential; uncorrected. The standard deviation of the observations is displayed in the feature property box, and is a good indicator of the accuracy of the GPS observations. A review of positional quality would determine the need for further refinement of the data set, such as post processing, or eliminating individual positions from a feature. The analysis can be automated by exporting data to a spreadsheet template to flag anomalous readings.

13.4.3 Post Processing

Post processing the GPS observations may be required if real-time corrections are not available during the field session, or if the analysis indicates questionable positions. The real-time data can also be differentially corrected to obtain a more accurate solution when needed. This is accomplished with longer occupation times and processing the carrier phase observable.

Post-processed differential corrections require a base file recorded at a known location in approximately the same region, which covers the same time span as the rover data. A number of base station operators distributed throughout the province of Alberta provide reference data to correct the GPS measurements. In addition to the two base stations currently operated by Alberta Transportation in Red Deer and Peace River, stations exist in Boyle, Calgary, Edmonton, Fox Creek, Grand Prairie, Whitecourt and Fort McMurray. Most of these operators provide the correction data on a fee-based system. The data from these base stations can be accessed and downloaded through electronic bulletin boards or through the Internet. The post-processed coordinates can be compared to the real-time values as a verification of accuracies.

13.5 FEATURE EDITING

Individual positions, entire features and attributes of a feature can be edited prior to exporting the data to the GIS. Through querying a feature or reviewing the position properties of a feature, the user can determine the need for editing. Editing positional and attribute information in Pathfinder Office is a comprehensive step that eliminates incorporating corrupt data into a GIS.

13.6 PLOTTING

The field data is displayed graphically on the computer screen during data collection and in Pathfinder Office. A plotting utility is available that enables the user to output daily plots of the collected data. This may be a useful tool for quality control purposes as the field and office personnel can view the daily plots and identify blunders.

13.7 DATA QUERIES

The Pathfinder Office and Aspen software contains tools to allow measurement queries between pairs of observed points, or from points to features on a background map. The software provides a utility in which the length and area of a linear feature captured can be calculated. This is an important quality control method used to detect blunders in the field.

13.8 EXPORT TO GIS FORMATS

Once the data set has been verified and edited, the final step is to export the combined positions and attributes of the features to the GIS database. A number of standard formats are available representing main stream GIS and CAD software packages (Arcview, MapInfo, AutoCAD, and MicroStation). The export utility allows for custom formats to suit the need of the specific platform.

The export utility provides the ability to filter, separate, or supplement the output formats based on positional quality indicators, correction method, or feature type. Once the appropriate settings have been determined, they can be saved in a user defined export format for reuse.

The above information highlights methods to incorporate quality control in the data collection process. Quality control is a function that is required at every stage of the data collection process, from mission planning to data export. Quality control is not only a specific procedure that needs to be performed, but also an overall approach to data collection. Quality control is better achieved through proper methodology throughout the data collection mission than performing quality assurance tests as a final step.

14. DATA DICTIONARY

The data dictionary is a tool for combining the GPS positions with descriptions and properties associated with the appurtenance. The data dictionary provides a uniform format and structure to the data collection sessions. When data collection is initiated, a feature-sensitive list (SIGN, GUARDRAIL, and CULVERT) is presented, from which a user is prompted for the properties of the feature, in an order compatible with the GIS or database structure.

The features in a data dictionary can be defined as points, lines, or areas. Point features average the GPS positions collected at each epoch of the occupation time for a final position. Linear features join the GPS positions to form a line, and area features connect the GPS positions to form an enclosed region.

The attributes of the feature can be defined as one of six types:

- Text
- Numeric
- Menu
- Date
- Time
- Filename.

The attribute fields can be designed to ensure data integrity and compatibility by limiting the input. The information can be screened for proper data types, confine key-in data to minimum and maximum values or supply default values and restrict the input to a predefined set of responses selected from a menu list.

The data dictionary must remain consistent throughout the course of a project, but be flexible to the dynamic needs of an inventory system. The data dictionary is typically edited by authorized personnel to avoid inconsistencies in the collection methods or final export formats. The dictionary is typically created prior to the data capture session, and uploaded to the field collection units. The Trimble GPS data collector systems discussed in this report (Aspen and Asset Surveyor) use the same data dictionary, providing a consistent format throughout the data collection process. The data dictionary developed for the pilot project can be found in Appendix D.

15. FIELD DEMONSTATION

A section of highway was selected to test the GPS data collection system. The test section is located south of the town of Beaumont on Secondary Highway 814, commencing at the intersection with Highways 625 and continuing south 23 kilometers to Highway 616. The pilot area contains a two-lane asphalt roadway with narrow shoulders, intersected by three secondary highways and five county roads. Appurtenances consisted of signs, guardrails, traffic lights, light poles, culverts, medians, pavement messages, and one bridge structure. The location of field approaches and their culverts were also considered as part of the pilot test.

AT&U supplied a Microstation design file of the test section for use as the graphical background map. The map contains the cadastral fabric and surveys compiled by the Parcel Mapping program, in addition to a centerline alignment of Highway 814. Aspen software does not support Microstation "DGN" file format directly and a conversion to a "DXF" format was performed prior to importing the background file. The conversion process did not compromise the data integrity or structure of the file. Trimble has provided assurance that support for DGN files will be found in future upgrades. The mapping projection used by AT&U for their GIS system is a 10° Transverse Mercator projection based on the NAD83 datum. The coordinate systems on all software and hardware equipment were configured accordingly to match the base map parameters.

A precise survey was performed observing the positions of the appurtenances, cadastral boundary markers, and pavement centerlines for relative accuracy comparisons. A real-time kinematic GPS system capable of centimeter level precision over the length of pilot area was used to perform the survey. The equipment consisted of Trimble 4000ssi's receivers, a TSC1 Survey Controller, and Pacific Crest radios to broadcast the real-time corrections. In addition to the appurtenances, the survey observed four Alberta Survey Control Markers evenly distributed throughout the project area. The resultant coordinates agreed within centimeters of the published ASCM values.

The accuracy and compatibility of the base map were confirmed by observing boundary markers identifiable on the cadastral file and verifying the road centerline at various locations. The differences between the observed and base map values of the cadastral corners were less than 2 meters, which is within the tolerance specifications of the parcel mapping compilation. The highway centerline represented on the map differed from the measured locations by an average of 0.5m easterly.

A total of 200 appurtenances were observed with RTK methods. Attributes included type and description of the appurtenances for future reference. The appurtenance types and characteristics facilitated the creation of a data dictionary to be used during the actual data collection phase of the pilot test.

The field demonstration equipment included the recommended data collection GPS system which consisted of a Trimble Pro XRS connected to a Fujitsu Stylistic 1200 pen-based computer running Aspen software and receiving Landstar DGPS corrections. The GPS / DGPS antenna was attached to the roof of the vehicle with a magnetic mount, and a Laser Atlanta Advantage laser ranging device was connected to provide the offset measurements. Other equipment included a Trimble GeoExplorer receiving DGPS corrections from a Pleiades CDPD modem, a Laser Technologies Impulse ranging device, and a Trimble TSC1 handheld controller with Asset Surveyor firmware.

After a brief explanation of the GPS system and concepts, the attendees of the presentation were given a hands-on demonstration of the data collection system, capturing pseudo-appurtenance features while navigating around the streets displayed on the background map. A data dictionary was utilized to input characteristics and attributes of features and the versatility of the system was demonstrated by attaching the GPS antenna to a backpack and collecting positions by physically occupying the point. Navigation to a previously collected feature was demonstrated and system compatibility was exhibited by utilizing the same data dictionary on the pen-based computer, the hand held data logger and the GeoExplorer platforms.

The data collection on the pilot section of Highway 814 was scheduled for November 20, 1998, at which time the appurtenance positions and attributes were recorded with the aforementioned equipment. The field crew consisted of two AT&U managers and a Focus Surveys consultant. The feature positions were collected by remote offset methods using a laser ranging device to provide the distance, and a manually keyed offset direction. The equipment performed well, although a loss of DGPS corrections was detected. The system was reset and the signal was re-acquired.

The data dictionary was used to identify and describe the appurtenances. Attendees experimented with the various methods of selecting attributes: pick list, write-in, or abbreviated code. Due to the large volume of data in the AT&U GIS, the sign inventory in particular, the pick list method of capturing attributes was cumbersome. Manipulation of the data dictionary and sign inventory is recommended if the data logger system were to be implemented as a primary source of data collection.

During the field demonstration, a 10-kilometer section of highway was surveyed with the recommended system, in approximately 6 hours. A total of 105 appurtenances were observed, however the productivity of the survey was limited due to a number of constraints. An estimated two hours was spent on discussion of the following:

- Measurement location and field methods.
- Pick list types versus full text input.
- Determination of correct sign number.
- Ambiguities of the sign catalog.

Data input difficulties due to unfamiliarity with the pen-based computer and handwriting recognition software exhausted an estimated two hours. Data collection of appurtenances, including travel to each sign, GPS occupation time and remote distance measurements filled the remainder of the field demonstration. In addition to the above, the participants of the field demonstration were not completely familiar with the intricacies of the sign catalog and productivity may have increased if sign maintenance personnel were involved in the data collection demonstration.

Data collection is dependent upon field conditions, distance between signs, number of sequences to a sign, GPS constraints and project requirements. Once field staff becomes familiar with equipment and methods for data collection, productivity can be expected to be approximately a third of the time of the field demonstration.

Some of the problem features discussed included: guardrails (point to point or linear ties); signs with multiple placards; signs not visible when performing the perpendicular offset method; culvert locations; and overhead or cantilevered sign tie methods. Many of these issues arise because the GPS driven data collection method provides appurtenances with two and three dimensional positions, as opposed to the one-dimensional position of the Linear Reference Model.

The truck-mounted configuration requires few safety precaution modifications, as the field demonstration indicated. However, when operators implement the backpack mounted system and traverse to appurtenances on the ground, additional safety procedures should be in place.

A sample data set in shown in Appendix E. The final format should require few format modifications to achieve compliance with the AT&U GIS database.

An additional field demonstration of the recommended GPS data collection system occurred on November 13, 1998. The scheduled events included data collection on the test section, but inclement weather (snow and blowing snow causing poor driving conditions and limited visibility) precluded travel to the site. Instead, the area surrounding the AT&U office was designated as an alternate venue, and a background map of the neighborhood was acquired and uploaded to the pen-based computer. The background map, compiled by the City of Edmonton Digital Mapping Department, contained graphical features similar to the pilot map, in addition to surface and sub-surface utilities, roadway, sidewalk and curb delineation, and several building footprints.

16. CONCLUSIONS

The investigation of the viability of using a GPS driven real-time data logger for collecting location and attribute information for GIS purposes led to the following conclusions. Real-time differential GPS methods are a viable tool for data collection when the accuracy requirements are ±2 meters. After a cursory review of manufacturers, the investigation concentrated on Trimble products, as a detailed manufacturer comparison was beyond the scope of this project and funding was limited.

The recommended systems consist of two interoperable configurations.

1. A truck mounted system with moving background map capabilities. The configuration includes the following equipment:

- Pro XRS integrated receiver and antenna (Trimble)
- Aspen software (Trimble)
- Pathfinder Office software (Trimble)
- Pen-based computer (Manufacturer of choice)
- The Advantage Laser (Laser Atlanta) or The Impulse Laser (Laser Technologies Inc.)
- A C-Band frequency Differential Correction Service (Landstar)

2. A backpack mounted system without a moving background map:

- Pro XRS integrated receiver and antenna (Trimble)
- Asset Surveyor software (Trimble)
- Pathfinder Office software (Trimble)
- TSC1 Hand Held Data Logger (Trimble)
- A C-Band frequency Differential Correction Service (Landstar)

The above components are interchangeable and the transition from one configuration to the other is simple, providing field staff with more flexibility when collecting data. A GeoExplorer hand held receiver is also recommended as a low cost navigation device.

The system is compatible with the AT&U NAD83 10TM coordinate system and presently requires a simple conversion in order to be compatible with Microstation Design File based maps. Trimble support for "DGN" files is expected in the future.

A demonstration of the recommended system included illustrating the data dictionary designed for the pilot project and the capabilities of the pick menu to attach attributes to appurtenances. Due to the large volume of data in the AT&U GIS, manipulation of the data dictionary and sign inventory is recommended to make the pick list more efficient. The demonstration also included collection of real-time GPS data of appurtenances, display of data on an electronic map, navigation to desired coordinates and illustrated QuickPlan, a field planning software.

The accuracy of the recommended system was qualified by testing RTD data against published coordinates (an absolute method) and previously surveyed appurtenances (a relative method). The relative accuracy of the system is 1.6 meters, which is consistent with the total estimated one sigma error of 1.8 meters. The data collected by the recommended system includes almost fully automated attribute data in addition to three-dimensional positions of appurtenances. The field data is formatted in a comma delimited file and can be exported to the AT&U GIS database. The data set of the selected appurtenances can be found in Appendix E and a digital format can be made available upon request.

GPS driven data collection systems increase the efficiency of data collection for GIS applications. The results of the pilot project demonstrate the benefits of GPS data collection over the present Linear Reference Model. The data collected in the pilot project includes 105 appurtenances over a 10-kilometer section of secondary highway #814. A productivity rate of 4 to 5 kilometers per hour can be expected given conditions similar to the pilot project and staff familiar with both the field procedures and equipment.

Appurtenance locations are geographic positions accurate to 1.6 meters (one sigma error). The locations are absolute and once in the database, do not require further editing. Relative locations based on mileage from a starting reference point need refinements if distances along the highway change, making geographic positions a more effective method of storing locations in a GIS than is currently implemented in the Linear Reference Model.

Position and attribute capture of the GPS driven data collection is almost fully automated and the electronic data collected in the field is easily downloaded once in the office. This significantly reduces data processing time as no manual data entry is required and data manipulation is simplified. The data collected during a field session requires downloading and verification before importation to the GIS database. Each full day of field data would require an estimated 1 to 2 hours of office processing. The safety requirements of the recommended truck mounted system are comparable to the present method of data collection, and the backpack-mounted configuration would require additional safety precautions.

The conclusions are not based on a direct productivity and cost comparison, as data was not available on the Linear Reference Model method. However, the conclusions indicate the benefits and estimated savings of a GPS driven data collection system as compared to current methods of data collection.

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www.racal-landstar.com
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www.trimble.com
www.visat.com

APPENDIX A

Table 5: Relative Coordinate Comparison (NAD83 - 10º Transverse Mercator)													
		Actual Coordinates					DGPS Observed Coordinates			Differences			Radial Distance
Feature		North	East	Elev.			North	East	Elev.	North	East	Elev.	(2D)
Sign	117	5908625.9	105461.5	717.3	SIGN	5	5908625.4	105462.1	717.7	0.5	-0.7	-0.4	0.8
Lightpole	116	5908623.9	105461.2	717.0	LIGHT	7	5908623.5	105461.7	716.8	0.4	-0.4	0.2	0.6
Sign	115	5908607.1	105463.9	717.1	SIGN	8	5908606.6	105464.8	716.6	0.5	-0.9	0.5	1.0
Sign	114	5908593.8	105463.9	716.8	SIGN	9	5908593.3	105465.0	715.8	0.5	-1.1	1.0	1.2
Sign						10	5908592.5	105482.3	713.0				
Guardrail	113	5908532.5	105478.5	716.9	N GR	18	5908532.1	105478.8	715.7	0.4	-0.3	1.2	0.6
Sign	112	5908514.7	105479.6	716.9	OV HEAD LIGHT	19	5908515.3	105480.3	715.7	-0.7	-0.7	1.2	1.0
Guardrail	111	5908501.2	105479.3	716.8	S GR	20	5908501.9	105479.9	715.5	-0.8	-0.6	1.3	0.9
Sign	145	5908342.0	105485.1	715.4	SIGN	21	5908342.8	105486.1	716.1	-0.8	-1.0	-0.7	1.3
Sign	144	5908275.1	105487.2	715.1	SIGN	23	5908275.3	105488.5	716.4	-0.2	-1.3	-1.3	1.3
Sign	142	5908204.6	105471.1	715.9	SIGN	25	5908204.9	105472.6	717.1	-0.3	-1.4	-1.2	1.4
Sign	143	5908204.5	105485.7	716.6	SIGN	26	5908204.9	105484.1	708.2	-0.4	1.6	8.3	1.6
Culvert						27	5908183.6	105467.8	717.5				
Culvert						28	5908129.3	105469.4	718.4				
Sign	148	5907844.3	105493.8	718.8	SIGN	29	5907844.1	105494.9	720.8	0.2	-1.2	-2.1	1.2
Culvert						30	5907658.1	105477.0	721.3				
Culvert						32	5907439.3	105480.6	723.3				
Sign	149	5907198.2	105490.1	724.8	SIGN	33	5907197.8	105491.0	725.5	0.3	-0.9	-0.7	1.0
Culvert						34	5906647.7	105491.8	724.3				
Sign						35	5906580.6	105520.4	723.3				
Culvert						36	5906261.6	105506.3	723.4				
Culvert						37	5905790.6	105542.7	725.0				
Sign	150	5905759.4	105519.1	722.9	SIGN	38	5905758.6	105520.0	724.3	0.3	-0.9	-0.7	1.0
Culvert						39	5905758.5	105543.7	723.7				
Sign	151	5905638.9	105521.6	722.1	SIGN	40	5905638.4	105521.6	722.3	0.5	0.0	-0.1	0.5
Sign	152	5905638.4	105540.0	722.2	SIGN	44	5905638.4	105540.4	722.6	0.0	-0.4	-0.4	0.4
Sign	161	5905508.8	105542.4	721.1	SIGN	45	5905508.8	105542.6	720.3	0.0	-0.2	0.8	0.2
Sign	160	5905487.9	105545.4	720.5	SIGN	46	5905487.9	105546.0	720.6	0.0	-0.6	-0.1	0.6
Sign	159	5905449.9	105561.6	720.2	SIGN	55	5905448.2	105558.6	710.2	1.6	3.0	10.0	3.4
Sign	157	5905438.4	105555.4	721.4	SIGN	51	5905437.5	105555.9	722.0	0.8	-0.5	-0.6	1.0
Sign	170	5905437.2	105512.2	721.2	SIGN	56	5905435.7	105512.4	717.3	1.5	-0.1	3.9	1.5
Sign	173	5905428.4	105512.0	720.4	SIGN	60	5905427.7	105511.9	721.3	0.7	0.1	-0.9	0.7
Sign	180	5905394.7	105523.5	719.5	SIGN	48	5905394.6	105525.3	680.9	0.2	-1.9	38.6	1.9
Sign	181	5905377.8	105526.0	719.6	SIGN	50	5905377.2	105526.4	714.3	0.5	-0.4	5.2	0.6
Sign	183	5905241.7	105548.7	717.9	SIGN	62	5905241.4	105549.9	718.8	0.3	-1.1	-0.9	1.2
Sign						63	5905241.2	105535.8	719.2				
Sign						61	5905240.9	105533.1	716.4				
Sign	184	5905123.5	105551.8	716.7	SIGN	66	5905123.0	105552.3	718.0	0.5	-0.6	-1.2	0.8
Sign	185	5904783.1	105541.8	714.4	SIGN	68	5904782.6	105542.4	715.7	0.6	-0.6	-1.4	0.9
Sign						67	5904782.6	105546.1	715.8				
Sign						79	5902197.4	105636.5	724.3				
Sign						77	5902183.5	105577.7	725.3				
Sign						78	5902180.5	105595.6	725.4				
Sign						80	5900844.5	105629.6	732.9				

Sign						81	5900395.2	105641.3	744.4				
Sign						83	5899986.8	105649.8	737.6				
Sign						84	5899617.2	105676.5	720.5				
Sign	1	5899275.6	105667.1	714.5	SIGN	85	5899275.7	105668.0	715.4	-0.1	-0.8	-0.9	0.8
Sign	2	5899211.4	105668.7	714.1	SIGN	87	5899210.9	105669.3	714.7	0.5	-0.7	-0.6	0.8
Sign	3	5899189.2	105685.0	713.7	SIGN	88	5899188.9	105684.6	714.8	0.3	0.4	-1.1	0.5
Sign	4	5899150.1	105669.9	713.2	SIGN	89	5899149.3	105670.2	714.1	0.8	-0.3	-0.9	0.8
Sign	6	5899102.7	105687.1	712.2	SIGN	92	5899102.6	105686.8	712.7	0.1	0.4	-0.5	0.4
Sign	5	5899096.6	105671.8	712.4	SIGN	90	5899097.0	105672.7	712.5	-0.3	-1.0	-0.1	1.0
Sign	8	5899035.7	105689.1	710.6	SIGN	102	5899037.0	105690.5	711.4	-1.3	-1.4	-0.9	1.9
Sign	7	5899028.8	105672.6	710.5	SIGN	93	5899028.0	105672.8	710.5	0.8	-0.2	0.0	0.8
Sign	9	5898985.2	105690.9	709.8	SIGN	103	5898984.7	105691.0	710.8	0.5	-0.1	-1.0	0.5
Sign	13	5898965.4	105670.1	709.8	SIGN	105	5898964.5	105670.9	709.6	0.9	-0.8	0.2	1.2
									Maximum	1.6	3.0	38.6	3.4
									Minimum	-1.3	-1.9	-2.1	0.2
									St. Dev.	0.6	0.8	6.8	0.6
									Average	0.3	-0.5	1.5	1.0

APPENDIX B

Cansel Survey Equipment
1-800-357-0561
mailto:veronica_sew@cansel.ca

Trimble Navigation Limited
1-800-767-4822
http://www.trimble.com/support/

Laser Technology Inc.
1-303-649-1000
http://www.lasertech.com/support.asp

Butler Survey Supplies (Edmonton) Ltd.
1-800-661-8816

Laser Atlanta
770-446-3866
www.laseratlanta.com

APPENDIX C

GPS DATA COLLECTION FIELD PROCEDURES

The following is a step by step list for field staff to follow when collecting data with a Trimble Pro-XRS receiver and Aspen software.

GETTING STARTED

Before the field staff begins data collection, several steps need to be taken to ensure that the system is running properly.

EQUIPMENT SETUP

- Place GPS antenna on roof of vehicle with magnetic mount and attach antenna cable
- Place GPS receiver inside vehicle, run antenna cable through window or door opening, and attach to receiver port.
- Place the pen computer in desired location and attach a serial cable from COM1 on the computer to the DB9 connection on receiver.
- Check all cables are fastened securely, and contain no knots or kinks.
- Check battery connection clips, always carry spare batteries.
- Turn on the computer, the GPS receiver will be turned on automatically when Aspen is started.

STARTING ASPEN

- The project should already be defined, and the background map & coordinate system pre-assigned. Alberta Transportation uses a 10TM datum for its GIS base and background maps.
- Open the project and confirm the GPS receiver is working properly and computing 3D GPS positions indicated on the Status Bar at the bottom of the screen.
- If ASPEN software is successfully receiving GPS positions then the message field at the bottom left will be blank and the other fields will display whether there is an RTCM link or not, the number of satellites being used, and the PDOP (positional quality indicator).

- The number of GPS satellites (SVs) must be more than 5 for an adequate 3D position (more is better), and the PDOP must be less than 6 (less is best).
- Confirm your position is correct on the background map.

DATA COLLECTION

- You must create a new data file before you can collect data. The ASPEN software does not automatically open a new file on startup.
- Select **File** / **New** to create a new data file. The file name should be distinct and in a format that allows both field and office staff to understand what, where and when the data was collected.
- The recommended file naming convention is **HHHYMMDD** where:
  HHH = Hwy Number i.e. 814, or 002
  Y = Last digit of current year
  MM = Month
  DD = Day
- Information about the current data dictionary is displayed at the bottom of the dialog box. Select a different data dictionary by clicking the **Dictionary** button, and selecting **AT&U.ddf**
- Select **Data** / **Collect Feature**. A menu of features in the current data dictionary appears. These are the named features that are defined in the data dictionary.
- Pull up to appurtenance at a perpendicular offset.
- Select feature to be captured and press **Begin**.
- Position the laser below the GPS antenna and determine offset distance.
- Enter azimuth manually
- Enter the necessary data in the attribute fields and observe the position for at least 60 seconds. The number of GPS positions observed is displayed on the status screen.
- If unable to read the information pertinent to the attributes, press **Pause** to halt the data logging, move vehicle (back up) so that it is possible to read the sign, and continue entering the data.
- Press **End** when the data has been input.
- Press **Resume** on the toolbar is receive GPS positions again
- Continue onto next feature.

APPENDIX D

The following is a text file of the data dictionary design and implemented in the pilot project.

AT&U, Dictionary, Highway Inventory
Sign, point, Sign
Sign Location, menu,
Inside Left,[IL]
Outside Left,[OL]
Inside Right,[IR]
Outside Right,[OR], default
Overhead Right,[OHR]
Overhead Left,[OHL]
Category, menu, Major or Minor
Major
Minor, default
On this Roadway, menu,
Yes, default
No
Roadway Code, menu,
C
R1, default
R2
R3
L1
L2
L3
J
Sign Offset, numeric, 0, 1, 5, 1
Sign Sequence, numeric, 0, 1, 16, 1
Sign Number - Desc, menu,
200 M,[WA106T]
300 m - TAB,[WC1BT]
ADVISORY SPEED,[WA7]
ALBERTA ROUTE MARKER,[IB2]
ANIMAL CROSSING,[WC13]
DANGER GOODS PROHIB,[RB69]
DANGER GOODS PRO TAB,[RB70T]
DANGER GOODS ROUTE,[RB70]
DANGER GOODS RT -TAB,[RB69T]
DIAL 9-1-1 - TELUS,[ID424]
DIRECTION - LEFT,[IB8TL]
DIRECTION - RIGHT,[IB8TR]
DIRECTION - STRAIGHT,[IB7T]
DISTANCE TO SIGNAL,[WB4T]
DISTANCE TO VARIABLE,[WC104T]
DOUBLE DIR & DIST,[IA206]
EAST (TAB),[IB11T]
HAZARD - LEFT,[WA105L]

- HAZARD - RIGHT,[WA105R]
- IMPORTANT INT. AHEAD,[WC104]
- INT'L AIRPORT,[IC11]
- INTERNATIONAL - TAB,[IC11AT]
- JUNCTION,[IB4T]
- KEEP RIGHT,[RB25]
- MAXIMUM SPEED,[RB1]
- MAXIMUM SPEED AHEAD,[RB5]
- MAXIMUM WEIGHT - TON,[RB63]
- NORTH (TAB),[IB10T]
- OTHER,[OTHER]
- PREPARE TO STOP,[WB5A]
- ROAD BAN,[RB201]
- RURAL CRIME WATCH,[ID221]
- SCHOOL AHEAD,[WC1]
- SCHOOL BUS AHEAD,[WC9]
- SECONDARY ROAD,[IB100]
- SHARP SHOULDERS,[WDA100]
- SIGNALS AHEAD (SYM),[WB4]
- SINGLE GUIDE SIGN,[IA200]
- SINGLE DIRECTION,[IA201]
- SINGLE DIR & DIST,[IA203]
- SOUTH (TAB),[IB12T]
- STEEP HILL,[WA21]
- STOP,[RA1]
- STOP AHEAD,[WB1]
- STRAIGHT & LT TURN,[RB42L]
- STRAIGHT & RT TURN,[RB42R]
- TRIPLE DIRECTIONAL,[IA207]
- TRIPLE DIR & DIST,[IA209]
- WEST (TAB),[IB13T]

Sign Number - Pick, menu,

- IA-200
- IA-201
- IA-203
- IA-206
- IA-207
- IA-209
- IB-2
- IB-4-T
- IB-7-T
- IB-8-TL
- IB-8-TR
- IB-10-T
- IB-11-T
- IB-12-T
- IB-13-T
- IB-100
- IC-11
- IC-11-AT
- ID-221

ID-424
RA-1
RB-1
RB-5
RB-25
RB-42-L
RB-42-R
RB-63
RB-69
RB-69-T
RB-70
RB-70-T
RB-201
WA-7
WA-21
WA-105-L
WA-105-R
WA-106-T
WB-1
WB-4
WB-4-T
WB-5-A
WC-1
WC-9
WC-13
WC-104
WC-104-T
WD-A-7
WD-A-100
OTHER

Sign Number - Key-in, text, 15

Panel Size Length cm, menu,

30
45
60
75
90
120
150
200
300
Other - Specify

Panel Size Height cm, menu,

30
45
60
75
90
120
150
200

300
Other - Specify
Support Type, menu,
4x4 Pressure Treated,[A]
4x4 Painted,[A1]
4x6 Pressure Treated,[B]
4x6 Painted,[B1]
6x8 Pressure Treated,[C]
6x8 Painted,[C1]
Steel Post,[D]
Banded to other,[E]
Other - Comment,[F]
Overhead Cantilever,[OC]
Overhead Sign Bridge,[O1]
Overhead - Other,[O2]
Steel beam W150x14,[S1]
Steel Beam W200x15,[S2]
Steel Beam W150x22,[S3]
Steel Beam W200x27,[S4]
Number of Supports, numeric, 0, 1, 5, 1
Condition Rating, menu,
Good
Fair
Poor
Image File Name, filename
Description, text, 50
Comments, text, 30

Culvert, point
Road Name, text, 30
District, menu,
1
2
3
4
5
6
7
8
9
10
Shop, text, 10
Date, date, auto, mdy
Location, menu,
Approach,[AP]
Centerline,[CL]
Connecting Road,[CR]
Type, menu,
Steel,[ST]
Wood,[WD]
Concrete,[C]

Tie Location, menu,
- Invert,[AP]
- Center,[C]

Length (m), numeric, 0, 0, 100, 0
Diameter (mm), numeric, 0, 100, 10000, 400
Condition, menu,
- Good,[1]
- Fair,[2]
- Poor,[3]

Drainage Grate, menu,
- Yes
- No, default

Remarks, text, 30

Guardrail - Point, point

Road Name, text, 30
District, menu,
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

Shop, text, 10
Guardrail Location, menu,
- Inside Left,[IL]
- Outside Left,[OL]
- Inside Right,[IR]
- Outside Right,[OR], default
- Overhead Right,[OHR]
- Overhead Left,[OHL]
- Median,[M]

Start Point, menu,
- N
- NE
- E
- SE
- W
- SW
- W
- NW

Guard Rail Type, menu, required
- Box,[BX]
- Cable,[C]
- Jersy Barrier,[J]
- W-Beam Single Rail,[W1]
- W-Beam Dual Rail,[W2]

W-Beam Double Mount,[W3]
Post Type, menu,
Conc,[C], default
Plastic,[PL]
Steel,[ST]
Wood,[WD]
% Good Condition, numeric, 0, 0, 100, 100
% Fair Condition, numeric, 0, 0, 100, 0
% Poor Condition, numeric, 0, 0, 100, 0, required
Comments, text, 30

Guardrail - Line, line
Road Name, text, 30
District, menu,
1
2
3
4
5
6
7
8
9
10
Shop, text, 10
Guardrail Location, menu,
Inside Left,[IL]
Outside Left,[OL]
Inside Right,[IR]
Outside Right,[OR], default
Overhead Right,[OHR]
Overhead Left,[OHL]
Median,[M]
Start Point, menu,
N
NE
E
SE
W
SW
W
NW
Guard Rail Type, menu, required
Box,[BX]
Cable,[C]
Jersy Barrier,[J]
W-Beam Single Rail,[W1]
W-Beam Dual Rail,[W2]
W-Beam Double Mount,[W3]
Post Type, menu,
Conc,[C], default

Plastic,[PL]
Steel,[ST]
Wood,[WD]
% Good Condition, numeric, 0, 0, 100, 100
% Fair Condition, numeric, 0, 0, 100, 0
% Poor Condition, numeric, 0, 0, 100, 0, required
Comments, text, 30

Lightpole, point
Type, text, 15
Comments, text, 30

Traffic Light, point
Type, menu,
Flashing Red,[FL]
Flashing Amber,[FA]
Traffic Control,[TS]
Pedestrian Crossing,[PD]
Other,[Other]
Post Type, menu,
Overhead Cantilever
Overhead Cable
Straight Post
Other
Comment, text, 30

Pavement Markings, point
Type, menu,
Rumble Strip
Centerline Tabs
Speed Bump
Edge Strips
Comments, text, 30

Median, point
Type, menu,
Raised
Level
Depressed
Tie Point, menu,
N
NE
E
SE
W
SW
W
NW
Center, default
Length (m), numeric, 1, 0.0, 1000.0, 0.0
Width (m), numeric, 1, 0.0, 500.0, 0.0

APPENDIX E

GPS Data Collection Pilot Project - Highway 814
Appurtenance Properties

SIGNS

ID	NAD83 - 10TM			Feature	Sign	Category	On This	Roadway	Sign		Sign Numb	Panel Size		Supports		Condition		Descriptior	Comments
	North	East	Elev		Location		Roadway	Code	Offset	Sequence	Code Pickl	Length	Height	Type	No.	Rating			
2	5908831	105458.3	717.736	Sign	OL	Minor	Yes	C	1	1	WB-5-A	200	120	Overhead (	1	Good			
3	5908831	105458	717.176	Sign	OL	Minor	Yes	C	1	2	WD-A-100	45	45	Overhead (	1	Good			
5	5908625	105462.1	716.984	Sign	OL	Minor	Yes	C	1	1	IB-100	45	60	4x4 Pressu	1	Good		PoST iN POOR conD	
6	5908626	105466.5	715.899	Sign	OL	Minor	Yes	C	1	2	IB-12-T	45	30	4x4 Pressu	1	Good		PoST iN POOR conD	
8	5908607	105464.8	715.876	Sign	OR	Minor	Yes	R1	1	1	RB-201	60	60	Steel Post	1	Good			
9	5908593	105465	715.103	Sign	OL	Minor	Yes	C	1	1	RB-1	60	75	4x4 Pressu	1	Good		70	
10	5908593	105482.3	712.269	Sign	OR	Minor	Yes	C	1	1	IB-100	45	60	6x8 Pressu	1	Good			
11				Sign	OR	Minor	Yes	C	1	2	IB-7-T	45	30	6x8 Pressu	1	Good			
12				Sign	OR	Minor	Yes	C	1	3	IB-100	45	60	6x8 Pressu	1	Good		625	
13				Sign	OR	Minor	Yes	C	1	4	IB-100	45	60	6x8 Pressu	1	Good		625	
14				Sign	OR	Minor	Yes	C	1	5	IB-13-T	45	30	6x8 Pressu	1	Good			
15				Sign	OR	Minor	Yes	C	1	6	IB-11-T	45	30	6x8 Pressu	1	Good			
16				Sign	OR	Minor	Yes	C	1	7	IB-8-TL	45	30	6x8 Pressu	1	Good			
17				Sign	OR	Minor	Yes	C	1	8	IB-8-TR	45	30	6x8 Pressu	1	Good			
19	5908515	105480.3	714.947	Sign	OR	Minor	Yes	R1	1	1	WB-5-A	200	150	Overhead (	1	Good			
21	5908343	105486.1	715.379	Sign	OR	Minor	Yes	R1	1	1	WB-4	60	60	4x4 Pressu	1				
22				Sign	OR	Minor	Yes	R1	1	2	WB-4-T	60	30	4x4 Pressu	1			300T ABMOUNTEDTOHIGH	
23	5908275	105488.5	715.641	Sign	OR	Minor	Yes	R1	1	1	IB-4-T	90	30	4x4 Painte	1	Good		Post Poor	
24				Sign	OR	Minor	Yes	R1	1	2	IB-100	45	60	4x4 Painte	1	Good	625		
25	5908205	105472.6	716.347	Sign	OL	Minor	Yes	C	1	1	RB-1	60	75	4x4 Pressu	1	Good		I00 SIGNANGLED	
26	5908205	105484.1	707.495	Sign	OR	Minor	Yes	R1	1	1	RB-1	60	75	Steel Post	1	Good		70	
29	5907844	105494.9	720.113	Sign	OR	Minor	Yes	C	1	1	RB-5	60	75	4x4 Pressu	1	Good		SIGN ANGLED	
33	5907198	105491	724.754	Sign	OL	Minor	Yes	C	1	1	WC-9	90	90	Steel Post	1	Good			
35	5906581	105520.4	722.582	Sign	OR	Minor	Yes	R1	1	1	WC-9	90	90	Steel Post	1				
38	5905759	105520	723.581	Sign	OL	Major	Yes	C	1	1	IA-209	300	200	4x6 Painte	2	Good	JCT AIRPORT 300MI.NISKU PARK 7KMEDMONTONINTERNATIO		
40	5905638	105521.6	721.533	Sign	OL	Minor	Yes	C	1	1	IC-11-AT	30	90	4x6 Painte	1	Good	EDMONTON		
41				Sign	OL	Minor	Yes	C	1	2	IC-11	60	90	4x6 Painte	1	Good			
42				Sign	OL	Minor	Yes	C	1	3	IC-D-T	60	90	4x6 Painte	1	Good		9 Km	
43				Sign	OL	Minor	Yes	C	1	4	IC-B-TR	60	30	4x6 Painte	1	Good	EDMONTON		
44	5905638	105540.4	721.835	Sign	OR	Minor	Yes	C	1	1	RB-1	60	75	Steel Post	1	Good		100	
45	5905509	105542.6	719.525	Sign	OR	Minor	Yes	C	1	1	RB-201	60	60	Steel Post	1	Good			
46	5905488	105546	719.875	Sign	OR	Minor	Yes	C	1	1	IB-100	45	60	4x4 Painte	1	Good		8l4	
47				Sign	OR	Minor	Yes	C	1	2	IB-10-T	45	30	4x4 Painte	1	Good		8l4	
48	5905395	105525.3	680.124	Sign	IL	Minor	Yes	C	1	1	IB-100	45	60	4x4 Pressu	1	Good			
49				Sign	IL	Minor	Yes	C	1	2	IB-12-T	45	30	4x4 Pressu	1	Good			
50	5905377	105526.4	713.595	Sign	IL	Minor	Yes	C	1	1	RB-201	60	60	Steel Post	1	Good			
51	5905438	105555.9	721.285	Sign	OR	Minor	No	C	1	1	RA-1	60	60	4x4 Painte	1	Good			
52				Sign	OR	Minor	No	C	1	2	WA-105-R	30	90	4x4 Painte	1	Good			
53				Sign	OR	Minor	No	C	1	3	RB-25	60	75	4x4 Painte	1	Good		BACK OF SIGN WEST	
54				Sign	OR	Minor	No	C	1	4	WA-105-R	30	90	4x4 Painte	1	Good		BACK OF SIGN WEST	
55	5905448	105558.6	709.507	Sign	OR	Minor	Yes	C	1	1	RA-1	90	90	4x4 Painte	1	Good			
56	5905436	105512.4	716.57	Sign	IL	Minor	No	C	1	1	RA-1	60	60	4x4 Painte	1	Good			
57				Sign	IL	Minor	No	C	1	2	Wa-105 R	30	90	4x4 Painte	1	Good			
58				Sign	IL	Minor	No	C	1	3	RB-25	60	75	4x4 Painte	1	Good		BaCK oF SIGN EASt	
59				Sign	IL	Minor	No	C	1	4	WA-105-R						Good		
60	5905428	105511.9	720.546	Sign	IL	Minor	No	C	1	1	RA-1	120	120	6x8 Painte	2	Fair		LEANING POSTS	
61	5905241	105533.1	715.707	Sign	OL	Minor	Yes	C	1	1	RB-1	60	75	4x4 Painte	1	Fair			
62	5905241	105549.9	718.104	Sign	OL	Minor	Yes	C	1	1	IC-11-AT	30	90	4x6 Painte	1	Good	EDMONTON		
63	5905241	105535.8	718.49	Sign	OR	Minor	Yes	C	1	2	IC-11	60	90	4x6 Painte	1	Good			
64				Sign	OR	Minor	Yes	C	1	3	IC-D-T	60	90	4x6 Painte	1	Good		9 Km	
65				Sign	OR	Minor	Yes	C	1	4	IC-B-TL	60	30	4x6 Painte	1	Good			
66	5905123	105552.3	717.237	Sign	OR	Major	Yes	C	1	1	IA-209	300	200	4x6 Painte	2	Good	JCT AIRPC	JCT Airpor	Sign Crooked
67	5904783	105546.1	715.062	Sign	OL	Major	Yes	C	1	1	IA-209	300	200	4x6 Painte	2	Good	JCT AIRPC	JCT Airport 300MI. Nisku Park 7KM Edmonton	
68	5904783	105542.4	714.994	Sign	OL	Minor	Yes	C	1	1	WC-9	90	90	Steel Post	1	Good			
70	5904519	105552.3	714.165	Sign	OL	Minor	Yes	C	1	1	WA-105-L	30	90	Steel Post	1	Good			
71	5904501	105552.5	713.563	Sign	OR	Minor	Yes	C	1	1	WA-105-R	30	90	Steel Post	1	Good			
74	5904520	105561.6	713.039	Sign	OR	Minor	Yes	C	1	1	WA-105-R	30	90	Steel Post	1	Good			
75	5904500	105561.7	712.917	Sign	OR	Minor	Yes	C	1	1	WA-105-L	30	90	Steel Post	1	Good			

77	5902183	105577.7	724.565	Sign	OL	Minor	No	C	1	1	RA-1	60	60	Steel Post	1	Fair		
78	5902180	105595.6	724.694	Sign	OL	Minor	Yes	C	1	1	ID 223				1		TWP RD 5OO RG RD242	
79	5902197	105636.5	723.608	Sign	OR	Minor	No	R1	1	1	RA-1	60	60	Steel Post	1	Good		
80	5900844	105629.6	732.188	Sign	OL	Minor	Yes	C	1	1	WC-9	90	90	Steel Post	1	Good		
81	5900395	105641.3	743.697	Sign	OL	Minor	Yes	C	1	1	WA-21	75	75	Steel Post	1	Good		
82				Sign	OL	Minor	Yes	C	1	2	WA-7	60	60	Steel Post	1	Good		80 Km
83	5899987	105649.8	736.842	Sign	OL	Minor	Yes	C	1	1	WC-104	120	120	4x6 Pressu	1	Good		DIAMOND GRADE ORANGE COLOR
84	5899617	105676.5	719.77	Sign	OR	Minor	Yes	C	1	1	WC-9	90	90	Steel Post	1	Good		
85	5899276	105668	714.695	Sign	OL	Minor	Yes	C	1	1	IB-4-T	90	30	4x6 Painte	1	Good		
86				Sign	OL	Minor	Yes	C	1	2	IB-100	45	60	4x6 Painte	1	Good		623
87	5899211	105669.3	714.029	Sign	OL	Minor	Yes	C	1	1	WB-1	75	75	4x4 Painte	1	Good		
88	5899189	105684.6	714.079	Sign	OR	Minor	Yes	C	1	1	ID-221	45	45	Steel Post	1	Good		
89	5899149	105670.2	713.344	Sign	OL	Minor	Yes	C	1	1	IA-209	300	200	6x8 Pressu	2	Good	WETASKIWIN34ROLLYVIEW6LEDUC8	
90	5899097	105672.7	711.826	Sign	OL	Minor	Yes	C	1	1	RB-69	60	60	Steel Post	1	Good		
91				Sign	OL	Minor	Yes	C	1	2	RB6IBT	60	30	Steel Post	1	Good		
92	5899103	105686.8	712.021	Sign	OR	Minor	Yes	C	1	1	RB-1	60	75	4x4 Painte	1	Good		l00 Km
93	5899028	105672.8	709.8	Sign	OL	Minor	Yes	C	1	1	IB-100	45	60	4x4 Painte	1	Good		
94				Sign	OL	Minor	Yes	C	1	2	IB-7-T	45	30	4x4 Painte	1	Good		
95				Sign	OL	Minor	Yes	C	1	3	IB-100	45	60	4x4 Painte	1	Good		623
96				Sign	OL	Minor	Yes	C	1	4	IB-100	45	60	4x4 Painte	1	Good		623
97				Sign	OL	Minor	Yes	C	1	5	IB-11-T	45	30	4x4 Painte	1	Good		
98				Sign	OL	Minor	Yes	C	1	6	IB-13-T	45	30	4x4 Painte	1	Good		
99				Sign	OL	Minor	Yes	C	1	7	IB-8-TL	45	30	4x4 Painte	1	Good		
100				Sign	OL	Minor	Yes	C	1	8	IB-8-TR	45	30	4x4 Painte	1	Good		
101	5899045	105676.1	711.1	Sign	OL	Minor	Yes	C	1	8	IB-8-TR	45	30	4x4 Painte	1	Good		
102	5899037	105690.5	710.731	Sign	OR	Minor	Yes	C	1	1	RB-201	60	60	Steel Post	1	Good		
103	5898985	105691	710.039	Sign	OR	Minor	Yes	C	1	1	IB-100	45	60	4x4 Painte	1	Good		
104				Sign	OR	Minor	Yes	C	1	2	IB-10-T	45	30	4x4 Painte	1	Good		
105	5898965	105670.9	708.856	Sign	OL	Minor	Yes	C	1	1	RA-1	120	120	4x6 Painte	2	Good		

GUARDRAILS

ID	NAD83 - 10TM			Feature	Road	District	Guardrail	Start	Type	Post	Condition			Comments
	North	East	Elev		Name		Location			Type	Type	Good %	Fair %	Poor %
1	5908848	105459.9	719.2	Guardrail	814	3	OL	NW	W1	Wood	100	0	0	
4	5908807	105469.5	759.148	Guardrail	8l4	3	OL	SW	W1	Wood	100	0	0	RTK Pos. Invalid
18	5908532	105478.8	715.002	Guardrail	814		OR	N	W1	Wood	100	0	0	
20	5908502	105479.9	714.773	Guardrail	8l4		OR	SE	W1	Wood	100	0	0	
69	5904525	105552.2	713.463	Guardrail	814		OL	N	W1	Wood	100	0	0	
72	5904493	105552.3	712.974	Guardrail	814		OL	SW	W1	Wood	100	0	0	
73	5904523	105561.6	713.046	Guardrail	814		OR	N	W1	Wood	100	0	0	
76	5904494	105561.7	712.977	Guardrail	814		OR	SE	W1	Wood	100	0	0	

CULVERTS

ID	NAD83 - 10TM			Feature	Road	Date	Location	Type	Tie	Length	Diameter	Condition	Comments	Drainage
	North	East	Elev		Name				Location					Grate
27	5908184	105467.8	716.737	Culvert	814	11/20/98	Approach	Steel	Center	10	400	Good		No
28	5908129	105469.4	717.685	Culvert	814	11/20/98	Approach	Steel	Center	10	400	Good		No
30	5907658	105477	720.592	Culvert	814	11/20/98	Centerline	Steel	Invert	0	400	Good	WEST INV	No
31	5907499	105479	722.408	Culvert	814	11/20/98	Approach	Steel	Center	0	400	Good	WEST -AP	No
32	5907439	105480.6	722.578	Culvert	814	11/20/98	Approach	Steel	Center	0	400	Good	WEST -AP	No
34	5906648	105491.8	723.613	Culvert	814	11/20/98	Approach	Steel	Center	0	400	Good	WEST SID	No
36	5906262	105506.3	722.634	Culvert	814	11/20/98	Centerline	Steel	Invert	0	400	Good		No
37	5905791	105542.7	724.245	Culvert	814	11/20/98	Centerline	Steel	Center	0	400	Good	EAST SIDE	No
39	5905759	105543.7	722.995	Culvert	814	11/20/98	Centerline	Steel	Center	0	400	Good	EAST SIDE	No

LIGHTPOLES

ID	NAD83 - 10TM			Feature	Comments
	North	East	Elev		
7	5908624	105461.7	716.04	Lightpole	SINGLE DABiT