INTEGRATING DIFFERENTIAL GLOBAL POSITIONING SYSTEMS AND GEOGRAPHIC INFORMATION SYSTEMS FOR ANALYSIS AND MAPPING OF SKELETAL DISPERSALS

by

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ABSTRACT

Scene mapping is an integral part of processing a forensic scene with scattered human remains. By utilizing the appropriate mapping technique, investigators can accurately document the location of human remains and maintain a precise geospatial record of this evidence at a scene. Global positioning system (GPS) units have been used for years to survey the spatial distribution of large-scale archaeological sites. However, differential global positioning (DGPS) unit now provide decreased positional error suitable for small-scale surveys, such as forensic scenes. Because of the lack of knowledge concerning this utility in mapping a scene, controlled research is necessary to determine the practicality of using DGPS in mapping scattered human remains in different environments. The purpose of this research is to quantify the accuracy of a DGPS unit for mapping skeletal dispersals and to determine the applicability of this utility in mapping dispersed remains. First, the accuracy of the DGPS unit was determined using known survey markers in different environments. Secondly, several simulated scenes were constructed and mapped in open, tree-covered, and structure-obstructed environments using the DGPS. Factors considered included the extent of the dispersal, data collection time, and the use of offsets. Data were differentially postprocessed and compared in a geographic information system (GIS) to evaluate the most efficient recordation methods. Results of this study show that the DGPS is a viable option for mapping human remains in open areas. Furthermore, guidelines for accurate scene mapping using a DGPS unit will be provided, along with a discussion concerning the integration of DGPS into GIS for scene analysis and presentation.

Dedicated to my fiancé Michael Stewart and my sister Raquel Walter,
for keeping me grounded both here and there.

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First, I would like to thank my chair and advisor Dr. John Schultz for his guidance and mentoring throughout my time at the University of Central Florida. Dr. Schultz has helped me to successfully make the transition from an undergraduate student to a professional in this field by providing me with several opportunities and experiences that have prepared me in my next step as a PhD student. It is because of his constant urging to go further, that I reached my full potential as a Master's student. Also, I would like to recognize my committee members, Dr. Tosha Dupras and Dr. John Walker, for providing the guidance and feedback necessary to successfully complete this thesis.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

The recent re-emphasis of methodological techniques in forensic archaeology is a development that has provided forensic anthropology with "a new conceptual framework, which is broader, deep, and more solidly entrenched in the natural sciences" (Dirkmaat et al., 2008:33). This shift is currently changing the goals of forensic anthropologists and how they approach situations in the field. Dirkmaat et al. (2008) attribute the current configuration of forensic anthropology to four developments: (1) improvement of field archaeology methods, (2) new technology, (3) new techniques used in the analysis of spatial data in the field, and (4) the emergence of recovery methods more geared toward forensic contexts. The implementation of technology in the field has resulted in the use of archaeological methods in a forensic setting. Site mapping has advanced from hand-drawn maps that note the distribution of evidence to the use of technology for recording specific locations of evidence and spatial data at the scene.

While standard global positioning systems (GPS) units generally do not offer the appropriate degree of accuracy for mapping (Listi et al., 2007), portable differential global positioning system (DGPS) units offer decimeter error margins which may be appropriate for mapping scattered remains. These enhanced units have the potential to collect accurate positional information of objects and provide the exact location of the object on the Earth. In instances where skeletal dispersal are widely scattered, a DGPS unit may be a useful tool. Thus, it is essential to determine the accuracy and practicality of using a mid-price DGPS unit in mapping skeletal dispersals and explore the value of DGPS in field recovery situations.

Controlled Research

As forensic archaeology is becoming more integrated into forensic anthropology, controlled research is essential in determining the utility of innovative technology in a forensic context. Controlled research is a necessary method of testing controlled variables in order to ascertain the best use of equipment in the field (France et al., 1992). Data collection of known points, such as survey markers, in controlled environments can assess the accuracy of DGPS units. Moreover, controlled environments and simulated dispersals can be utilized to apply and evaluate the best methods for collecting point data in these environments.

Limited research has been conducted concerning the use of DGPS in the mapping of skeletal remains. Listi et al. (2007) determined that the use of a mid-price traditional GPS receiver is not as accurate as traditional mapping techniques because of limiting factors such as tree cover density, proximity of remains to structures and trees, and the positioning of satellites which can result in erratic data. This preliminary research underlines the necessity of assembled scenarios wherein different settings and variables can be controlled and tested to assess the accuracy of using a DGPS in mapping skeletal dispersals. Additionally, the determination of accuracy of a DGPS in different environmental scenarios is necessary to evaluate the practicality of using this utility in mapping human remains. Furthermore, research has not been conducted concerning the use of georeferenced data in skeletal dispersals. The integration of exact coordinates to survey data is ideal, as this provides a highly accurate record of the scene, along with the ability to manipulate survey data in a geographic information system (GIS) to maintain geospatial information (Wu et al., 2004).

Finally, the use of GIS in forensic investigations has generally been limited to crime mapping, rather than with individual scenes (Spencer et al., 2003; Manhein et al., 2006). It is because of this lack of published research that it is necessary to utilize these new technologies to determine the advantages and disadvantages in the field. Additionally, the practicality of using DGPS units in different environments can aid in the development of efficient and accurate methods for data collection, maximizing point accuracy and information of skeletal elements and associated evidence at a scene. Thus, controlled research concerning different mapping technologies in different environmental scenarios is essential in order to expand knowledge of new technology in the mapping of scattered remains. Furthermore, it is necessary to experiment with these technologies to determine their practicality and applicability in the field, supporting the current shift of integrating new technology and techniques in forensic archaeology.

Research Objectives

The primary objective of this research is to compare different data collection techniques using the DGPS in the mapping of simulated skeletal dispersals in varying scenarios and to discuss the benefits of mapping these scenes using the DGPS with the integration of GIS for data analysis and presentation. This research will (1) determine the accuracy of using a DGPS unit in differential environmental scenarios; (2) construct different scenarios in order to simulate scenes that may be encountered in real-life forensic cases; (3) collect geospatial and attribute data of features from skeletal dispersals using the DGPS; (4) process, analyze, and generate maps of the data in GIS; and (5) discuss the benefits, disadvantages, and methods of using DGPS and GIS for scene mapping of skeletal dispersals in different scenarios. The final chapter of this thesis will summarize the findings of the research conducted. The results of this study will contribute to the formulation of guidelines for using a DGPS unit in mapping skeletal dispersals and integrating the DGPS data into a GIS.

Thesis Outline

This thesis will be divided into four chapters: the first chapter will provide an introduction into the research project; the second chapter will determine the accuracy of the DGPS unit in different environments; the third chapter will determine the practicality and accuracy of using a DGPS by constructing simulated scenarios, and the fourth chapter will discuss the integration of DGPS data into a GIS for analysis and mapping. The final chapter will also provide guidelines for using a DGPS unit when mapping scattered human remains.

CHAPTER TWO: ACCURACY DETERMINATION OF DGPS UNIT USING SURVEY MARKERS

Introduction

Accuracy is how close a value is to the true value, while precision refers to the way in which the data is measured or stored (Wheatley and Gillings, 2002). Unfortunately, accuracy is often difficult to measure as the true value is generally not known, except by the data collected. With precision, the more advanced or finer the unit of measurement that can be measured by an instrument, the more precise the data is said to be. Both accuracy and precision are important for recording a scene with forensic significance; however, for reconstruction purposes, accuracy is generally more important in forensic investigations (Gardner, 2004).

Innovative technology of DGPS units has enabled investigators to attain a higher level of accuracy than ever before. A high level of accuracy is essential particularly for scenes involving human remains. The accuracy of DGPS units has increased over the years from advancements of spatial technology; however, even the most advanced DGPS units cannot control certain factors during acquisition of positional information. Thus, it is imperative to recognize these limitations and integrate this into data collection and analysis.

Though extensive research has been conducted to determine the influence of certain variables on the accuracy of GPS, limited research has been conducted concerning the use of DGPS in the mapping of human remains to ascertain the effect of these variables. Listi et al. (2007) assessed the use of a standard GPS unit with the addition of a beacon receiver for mapping scattered human remains at a scene. The authors determined that the low-priced GPS unit generated a positional error of less than one-half meter; however, the GPS unit could not distinguish features that were in close proximity to each other when data was collected with a 100-second collection time. As with their previous study (Listi et al., 2003), the authors concluded that using a GPS was not as reliable as traditional mapping techniques. It must be noted, however, that the DGPS receiver used by the authors has become obsolete and models that are more accurate have been developed in the last four years that offer decimeter accuracy with postprocessing. Thus, it is crucial that the accuracy of these new and enhanced DGPS units be assessed within multiple environmental scenarios so that these error determinations may be applied in the field.

Purpose

The purpose of this chapter is to determine the accuracy of the DGPS unit in different environments by collecting point data at known survey markers for 50-second and 100-second collection times in various settings. Additionally, the distance accuracy of the DGPS unit will be determined by comparing maximum distance measurements of long bones with collected point data of the long bones at proximal and distal ends. Furthermore, the determination of collecting proximate bones as separate features or as a single feature was also considered. Bones were measured at distances of 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, and 30 cm to determine the best data collection method of clustered skeletal elements.

Differential Global Positioning Systems Theory

To understand the variables that affect the accuracy of a GPS unit during data collection, it is first important to understand the components and basic mechanics of GPS. Global positioning systems is a satellite-based positioning system involving 24 satellites circling the earth (El-Rabbany, 2006). A GPS receiver uses positional information from these satellites to calculate the position of an object on the earth (El-Rabbany, 2006). The development of a differential global positioning system (DGPS) allows more accurate point positions, which may be utilized to document the position of specific objects, such as skeletal elements and additional features, at a scene.

A DGPS unit is a more accurate enhancement of a standard GPS unit that requires two receivers; one remains stationary while the other records positional data (Figure 1). The stationary receiver, a basestation, relates all of the satellite measurements onto a single local reference (El-Rabbany, 2006; Napton and Greathouse, 2009). The basestation measures the timing errors and provides correction information to the other receiver during postprocessing. Differential postprocessing software obtains known basestation information via the internet and then compares this information to the mapped point data (Figure 2) for increased positional accuracy (Spencer et al., 2003). Furthermore, DGPS units are handheld units that are compact and easy to transport to and from the scene, and only a single operator is necessary to collect positional information (Napton and Greathouse, 2009).

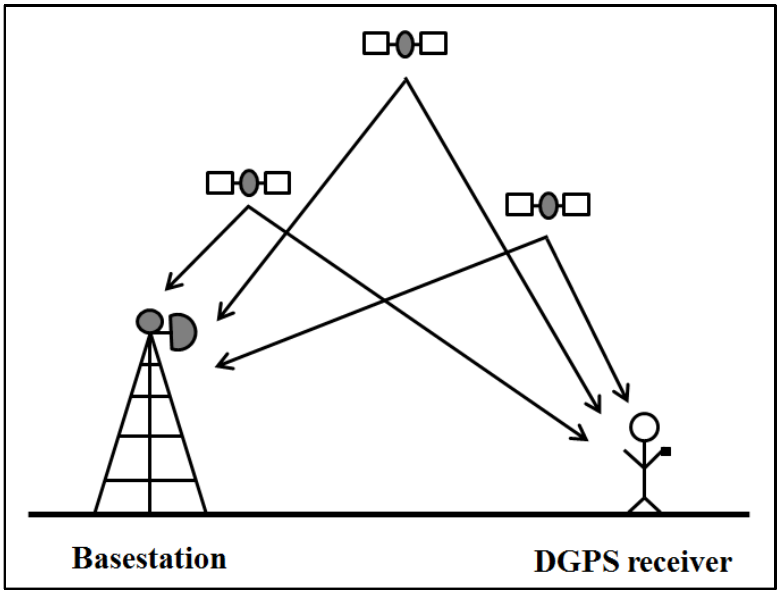

Figure 1- Differential GPS positioning

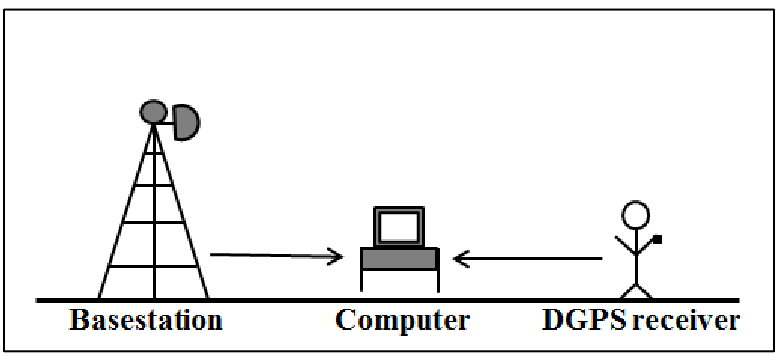

Figure 2- Illustration of postprocessing for differential GPS correction

Sando et al. (2005) categorize GPS receivers into three main configurations in the United States (Table 1): autonomous, wide area augmented system (WAAS), and continuously operating reference station (CORS). Autonomous configuration is the simplest mode, using a single receiver and three satellites to determine the current location. Wide area augmented system uses both land-based control stations and geostationary satellites to adjust GPS data to improve accuracy and was developed in order to provide accurate aircraft navigation. This technology is a correction service that was created at no extra charge for all WAAS enabled GPS receivers to achieve 3.0 m accuracy or less with multiple fixes and 7.0 m accuracy with single fixes (Bolstad, 2005; Sando et al., 2005). This system was originally developed for military use and has recently become available to the general public when using a GPS enabled with NAVSTAR technology (Bolstad, 2005). Like differential postprocessing, signals from satellites are received by ground reference stations through North America and correction information is calculated and then broadcasted to GPS units with NAVSTAR technology automatically. Currently, two WAAS satellites are in place over the Atlantic and Pacific Oceans (Sando et al., 2005).

The configuration used for this project, the CORS network, provides the most accurate positional information. The CORS network is available to the public in order to improve the precision of collected positions (Bolstad, 2005). Positional data is collected from several basestations in the CORS network and is used to differential correct positional data collected in the field or with postprocessing. Postprocessed CORS data requires differential processing against CORS basestation data that is retrieved from the internet. Data collected via CORS configuration can also be used for real-time correction if the GPS unit has the capability of connecting to the internet in the field. Any DGPS receiver within the range of the radio beacons can access the CORS network with either an antenna or additional beacon receiver. According to Bolstad (2005), the federal government is looking to extend the CORS network to all areas of the United States, but as of now, only certain locations can use CORS technology because of the limited locations of CORS radio beacons.

Table 1- Summary of the three main GPS configurations used in the United States

Autonomous	Wide Area Augmented System (WAAS)	Continuously Operating Reference Station (CORS)
• Simplest mode • Least accurate • Uses single receiver and 3 satellites	• Free correction service from the US military • Uses land-based control stations and geostationary satellites • Used to achieve at least 3.0 m accuracy with multiple fixes • Available to GPS units with NAVSTAR technology	• Most accurate • Requires postprocessing • CORS data available over the internet • Can be used for real-time correction • Not available in all areas of the US

Several influences can limit the accuracy of points recorded by a DGPS receiver such as cloud cover, satellite position, and obstruction of satellites from buildings and tree cover (Sando et al., 2005). Prior to 2000, selective availability was a heavily influential factor in the inaccuracy of DGPS positional data. Selective availability was a protective feature imposed by the United States Department of Defense that artificially deteriorated clock and ephemeris data for civil users (Bolstad, 2005). In 2000, President Clinton requested that selective availability be removed from satellite signals captured by civilian GPS units. Since selective availability was lifted by the federal government in May of 2000, studies have been conducted to ascertain the improvement of accuracy by GPS units (Graettinger et al., 2001). Graettinger et al. (2000) reported an improvement in accuracy up to 10-fold after the removal of selective availability. Furthermore, a three year study by Sando et al. (2005) demonstrated considerably higher accuracy when compared with the Graettinger et al. (2001) study.

Though Selective Availability no long produces inaccuracies during the acquisition of positional information, several other sources of error still occur. Ionospheric and atmosphereic delays can introduce error when satellite signals travel through the ionosphere and atmosphere. Changes in charged particle density in the ionsphere and changes of atmospheric density from temperature change in the atmosphere can affect the travel speed of the satellite signals (Lechner and Baumann, 2000). Differential GPS units, however, use dual frequency receivers to differentially correct this information by comparing the information collected by the receiver and the basestation take into account these changes and create sophisticated base models to reduce error (Bolstad, 2005). An almost negligible source of error can be from unsychronization of the atomic clocks on the satellite. This, however, is also corrected in postprocessing (Bolstad, 2005; Trimble Navigation Limited, 2009).

The geometry of satellites positions can also affect the positional error of a DGPS receiver. Satellites are most accurate when they are spaced farther apart, as close-set satellites overlap, causing areas of positional uncertainty when signals intersect (Bolstad, 2005). The geometry of a constellation of satellites is expressed by a number called the Dilution of Precision (DOP). Types of DOP include, Vertical DOP (VDOP), Horizontal DOP (HDOP), and Positional DOP (PDOP). Positional DOP is the most commonly used in the determination of complementary satellite geometry and is defined as the "ratio of the volume of a tetrahedron created by the four most widespread, observed satellite to the volume defined by the ideal tetrahedron" (Bolstad, 2005:183). The composition of an ideal tetrahedron includes one overhead satellite and three surrounding satellites spaced at approximately 120-degree intervals. The PDOP is expressed as a number with the ideal tetrahedron being 1. The closer the satellites are to each other, the less accurate the satellite geometry, increasing the PDOP number (Johnson and Barton, 2004). Thus, a lower PDOP is more desirable. DGPS receivers will automatically choose the satellite constellation with the lowest PDOP. Positional DOP is predetermined and can be acquired using planning software before data is collected.

Multipath signals are the most common source of error in standard GPS and DGPS units. Multipath signals are signals from satellites that are reflected off of obstructions between the receiver and the satellite such as clouds, trees, and structures (Lechner and Baumann, 2000). Because these signals are reflected, the signals travel a further distance than direct satellite signals, introducing an offset into satellite positions (Lechner and Baumann, 2000). These multipath signals are also usually screened out by antennae, but can still influence point collection (Bolstad, 2005).

Materials and Methods

The differential GPS unit used for this research was a Trimble GeoExplorer 2008 Series GeoXH handheld differential GPS receiver with Zephyr antenna (Figure 3). The receiver uses a field computer powered by Microsoft Windows Version 6 operating system and Terrasync software. The receiver uses both H-star and EVEREST multipath technology to provide heightened accuracy after postprocessing using the internal antenna. The addition of the external Zephyr antenna provides better locational recordation with 10 cm to 30 cm accuracy when data is differentially postprocessed (Trimble Navigation Limited, 2009). Interestingly, in 2005, Sando et al. found that when an older model of this DGPS unit was compared to three similar receivers, the Trimble GeoExplorer receiver was the most accurate.

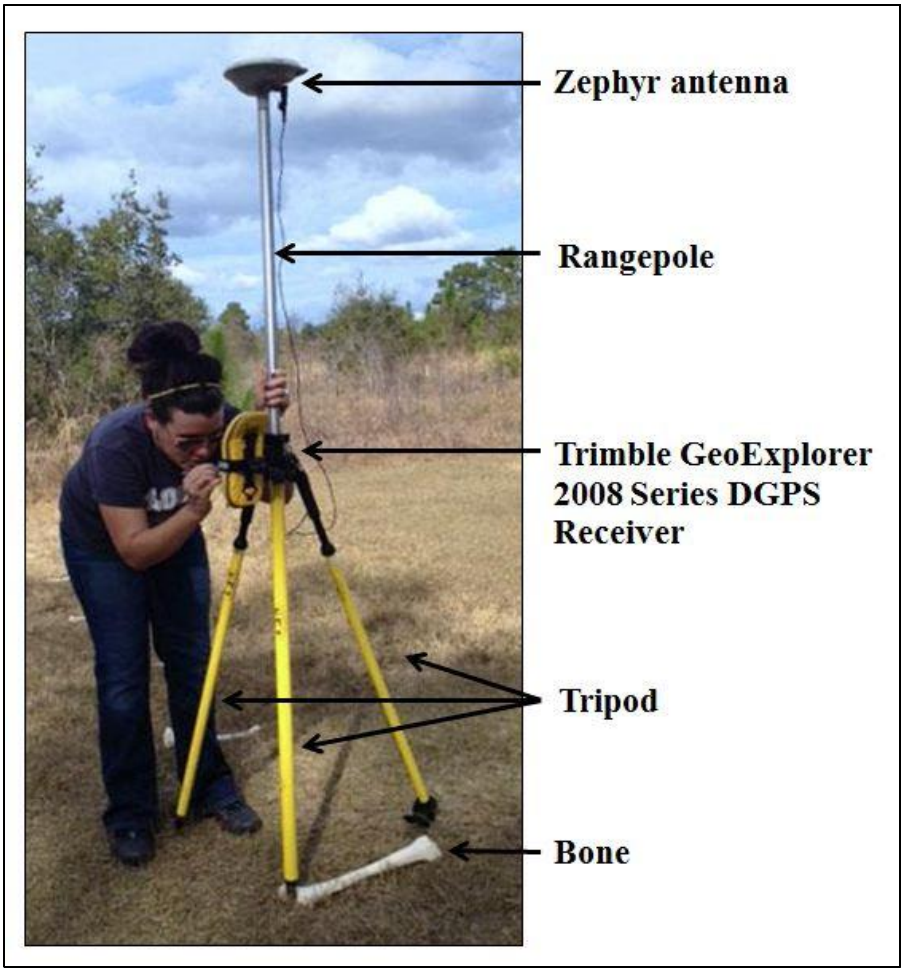

Figure 3- Figure of DGPS and antenna with labeled components

The use of an external antenna increases the accuracy of GPS data in three ways (J. Robeson, personal communication, March 12, 2012). First, by placing the antenna on a rangepole, the antenna is anchored to an associated point on the ground that holds the configuration in plumb. The operator is, thus, given a definitive point on the ground that they intend to map. Secondly, by placing the antenna above the operator, the GPS and its accuracy are not suffering from the abstraction the operator creates with his or her own body. Finally, by using an antenna that is of a higher quality, such as the Zephyr, the quality and strength of the signal is increased drastically. The Zephyr also adds an additional frequency antenna to the single frequency DGPS unit. The reception of both frequencies creates a higher accuracy position due to the GPS receiver and software's ability to process both frequencies per satellite. These frequencies are typically associated with survey-grade DGPS units because of its ability to calculate a far higher level of precision.

Controlled Points

Survey markers, or benchmarks, are known points on the earth maintained by various federal and state agencies such as the Department of Transportation (Bolstad, 2005; Sando et al., 2005; Dupras et al., 2011). It is common to find these points at road intersections, city centers, and other areas of interest, as these points are the basis for defining property boundaries. The exact coordinates, location, and description of these survey markers may be obtained from the government for various reasons. Currently, survey markers are most often determined using high-precision GNSS technologies, such as commercial-grade DGPS units and are accurate to the sub-centimeter (Bolstad, 2005; Sando et al., 2005).

Survey markers have previously been used in civil engineering studies to ascertain the error of various GPS units (Graettinger et al., 2001 and Sando et al., 2005). This study will also utilize survey markers as known points on the earth to determine the error of the Trimble GeoExplorer 2008 Series DGPS unit. The coordinates of the known points used for this project were provided by the Department of Transportation of the State of Florida and consist of 2 points in open areas, 1 point in an area under tree cover, and 1 point in an area near a tall structure (Figure 4). The survey markers were located within 5 kilometers of each other on New York Ave. in Deland, Florida (Figure 5). See Appendix A for survey marker information provided by the Department of Transportation.

Figure 4- Images of reference markers for survey markers 90501004, 90501007, VOLV119, and 90501006 provided by the Florida Department of Transportation

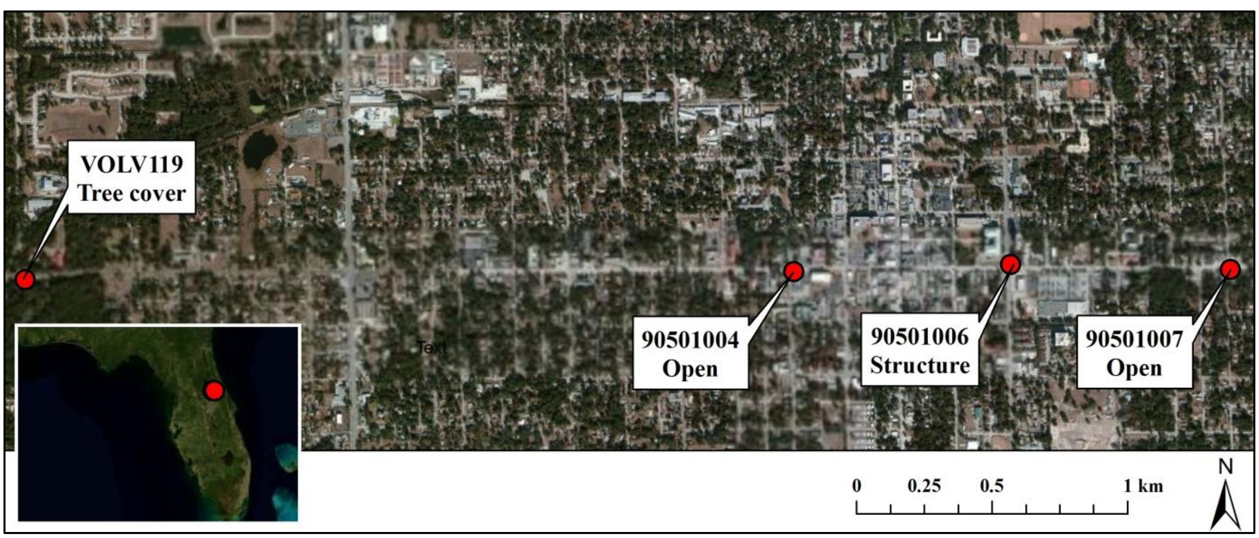

Figure 5- Labeled map of survey markers with environment type in Deland, FL

Distance Accuracy

In addition to the aforementioned survey marker scenarios, the mapping of proximate bones as separate features or as clusters were analyzed by mapping bones at 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, and 30 cm distances. The 5 cm distances were chosen to consider the different levels of clustering and to apply these systematic distances to long bone lengths. Additionally, the accuracy of the DGPS unit in mapping long bones will be determined by comparing maximum distance measurements of long bones with collected point data of the bones at proximal and distal ends at both 50-second and 100-second collection times. The results from the analysis of these data will then be applied to data collection for the simulated scenarios in Chapter 3.

Data Collection

Prior to the day of data collection, planning almanac software (available through Trimble) was consulted to determine the best time for data collection. This software provides information including the satellite position data, DOP data, and elevation data on specific days (Figure 6). The best time for data collection on a day was determined by considering the greatest number of satellites, with at least 4 satellites being the most desirable, and the least PDOP value, with values less than 2 being the most desirable (Johnson and Barton, 2004; Bolstad, 2005). Data collection was then conducted during this time period if weather permitted. See Appendix B for planning information for each day of data collection.

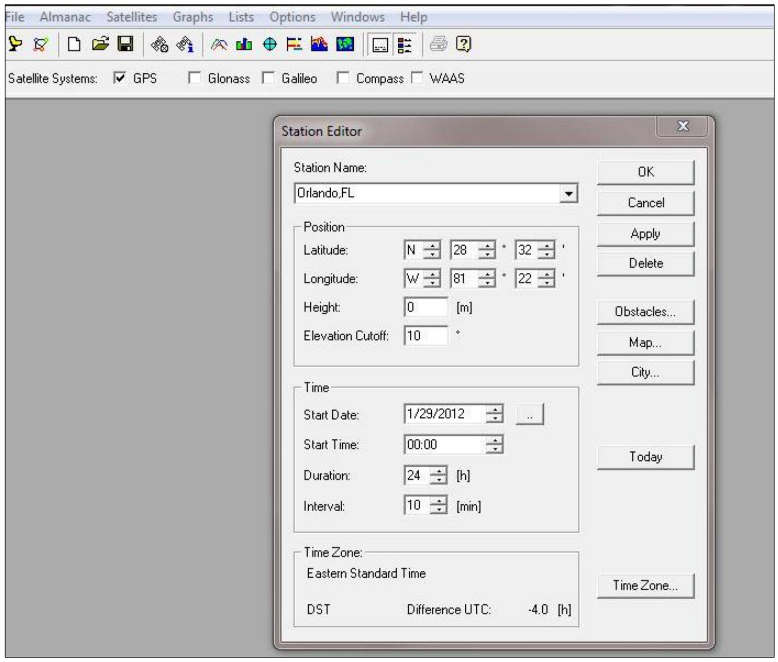

Figure 6 - Screenshot of data collection planning using Trimble Planning Software

In addition to planning the best time of day of data collection, the orientation of the DGPS receiver was also considered. Vertical orientation of the GPS receiver has been found to significantly influence accuracy, with vertical orientation of the receiver yielding coordinates that are more accurate, rather than horizontal orientation (Sando et al., 2005). Data were collected in US State Plane 1983, Florida East, with the NAD 1983 Conus datum, as this is the coordinate system and datum used by the Florida Department of Transportation in Deland, Florida. By using the same coordinate system and datum, additional error will not be introduced during processing and export from changes in the projection of the systems. Point data were collected using the batch method, which is the average of the point data in 1-second intervals. For example, a batch reading for a point collected at 1-second intervals for 50 seconds would yield the average of 50 points collected at that location. The collection times for this research were chosen in accordance with the 100-second collection used in previous research (Listi et al., 2007), with the addition of the more efficient 50-second collection time for comparison purposes. The following information was recorded by the DGPS during point data collection:

- Date
- Time
- Northing
- Easting
- Max HDOP
- Max PDOP
- Correction Type
- Receiver Type
- Filtered and unfiltered positions
- Feature Name (*i.e.* Bone)
- Data dictionary used
- Filename

Point data were collected at each survey marker in 1-second intervals for 50 seconds and 100 seconds (Figure 7). Using this method, 25 points were collected consecutively for each survey marker at both 50-second and 100-second time intervals. Fifty-second and 100-second data were collected on different days because of time limitations that conflicted with planning times. Further, data were collected using a predefined data dictionary with survey marker, collection interval, environment type, and notes (Figure 8). These attributes were later exported into ArcGIS with the point data for analysis and creating maps.

Figure 7- Point data collection using the DGPS unit at survey marker VOLV119

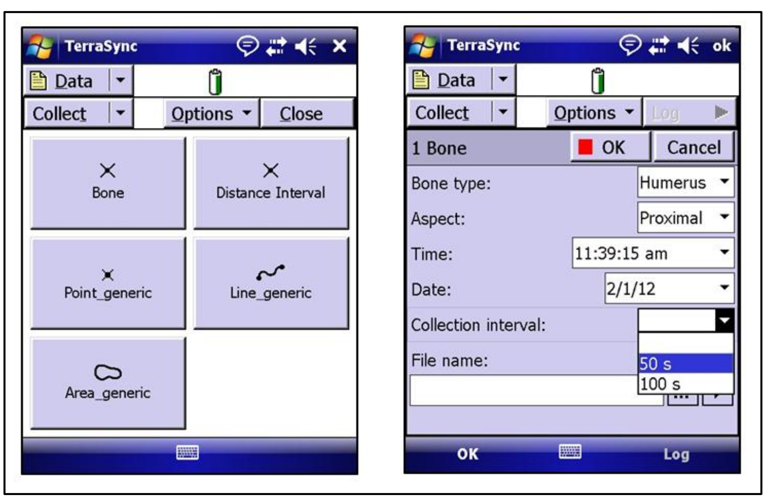

Figure 8- Screenshot of data dictionary used during data collection in Terrasync

Data Processing

After point data were collected in the field, unprocessed data were transferred to a desktop computer using ActiveSync. This data was then imported into Pathfinder Office for differential postprocessing (Figure 9). Postprocessing capabilities refer to the ability of the GPS receiver to store GPS system data in a format that can be used to compute differential corrections of the location data using corrections recorded at a reference receiver to improve locational accuracy (Bolstad, 2005; Trimble Navigation Limited, 2009). Uncorrected data was differentially postprocessed against the closest public basestation in Deland, Florida (CORS96), approximately 8 kilometers from the mapped area (integrity index = 94.7), using Pathfinder Office. The integrity index is a grading system by Trimble that monitors basestations used for differential processing and rates a basestation on its reliability, accuracy, and precision (Trimble Navigation Limited, 2004). Additionally, the integrity index value for a basestation is adjusted in consideration of the proximity of the basestation to where the data was collected by the rover unit. Trimble recommends postprocessing against a basestation with an integrity index of 80 or higher that is within 200 kilometers of the site (Trimble Navigation Limited, 2009). It is important for the basestation to be in close proximity (a maximum of 200 km) of the roving receiver, as this will allow the receiver and basestation to collect data from the same satellite constellation and produce less error during differential postprocessing (Bolstad, 2005). Processed data were then exported into ArcGIS 10 for analysis in ArcMap. The GIS software used for this research was the latest version of ESRI ArcGIS, version 10 and included the use of ArcCatalog and ArcMap.

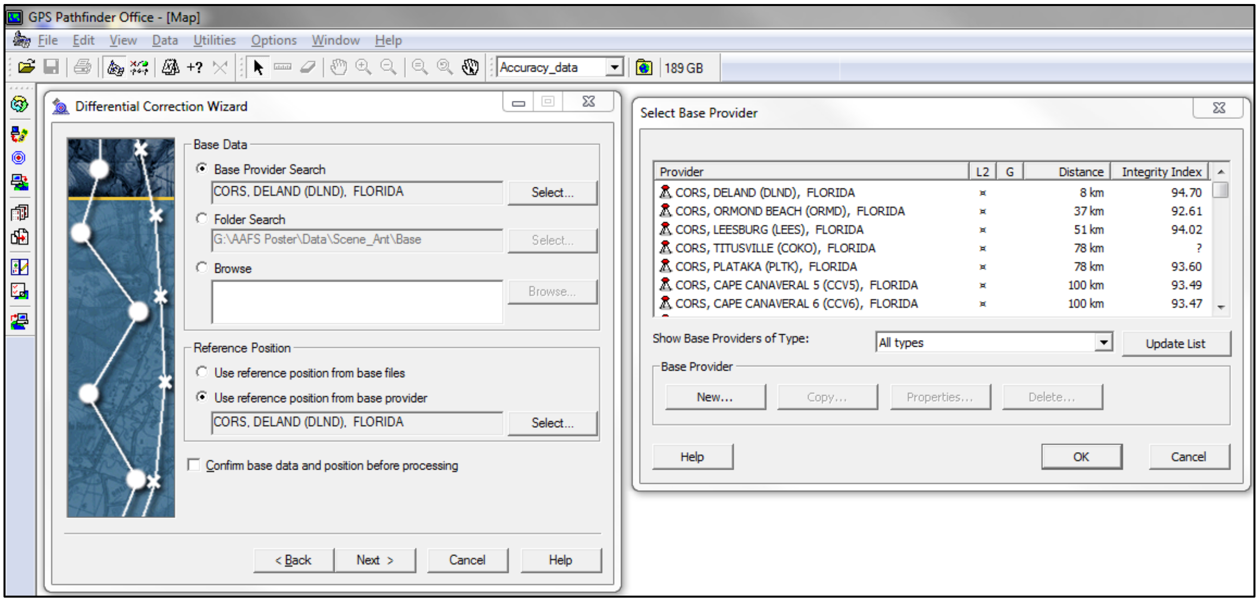

Figure 9- Screenshot of differential postprocessing using Pathfinder Office

A geodatabase was created for each scenario to organize the collected data (Figure 10). This was accomplished by creating shapefiles from the exported data and grouping these shapefiles into feature datasets. A shapefile is a filetype used in GIS that is a non-topological digital storage format used to store the geometric location of features on a map and includes collected attribute information. Additionally, the filetype allows the easy projection change from one coordinate system to another without losing substantial positional information (Bolstad, 2005). For comparison purposes, coordinate data of the survey markers were also imported into the geodatabase as a shapefile using Microsoft Excel and the XY data tool in ArcGIS.

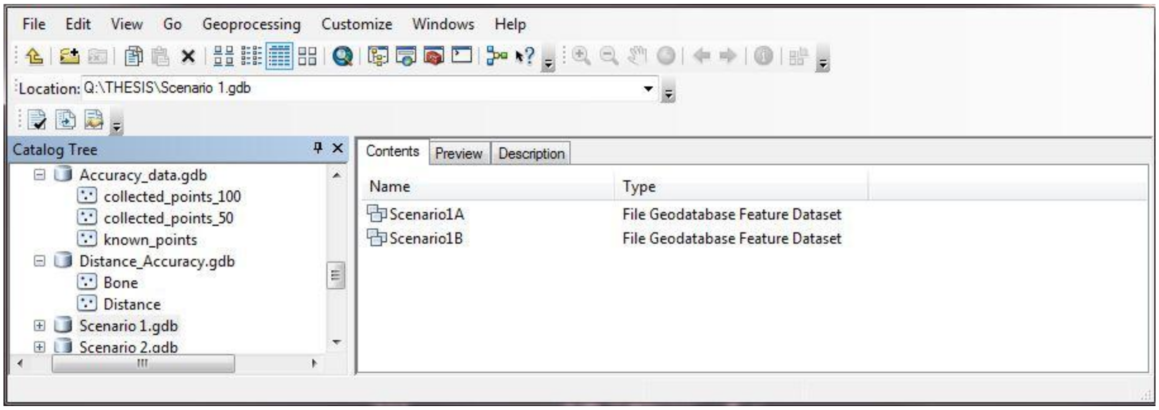

Figure 10- Screenshot of geodatabase for accuracy data in ArcCatalog

These methods (Figure 11) were first used for the 50-second collection time data and subsequently used for the 100-second collection time data. The 50-second and 100-second were then analyzed to determine accuracy of the collected points to the survey markers.

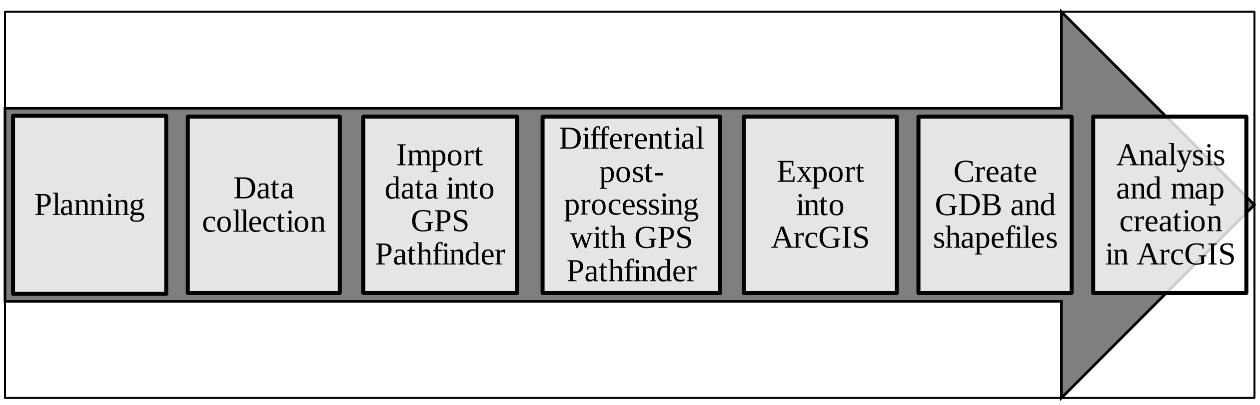

Figure 11- Flowchart of data planning, collection, processing, and analysis methods

Calculating Accuracy

Per Sando et al. (2005), the following formula was used to determine the accuracy of the collected points:

$$Accuracy = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}$$

Where x_i is the collected horizontal coordinate, x_0 is the known horizontal coordinate, y_i is the collected vertical coordinate, and y_0 is the known vertical coordinate. The accuracy was calculated by exporting attribute data into Microsoft Excel version 10 and using the formula tool. Accuracy data were then imported into GIS as attribute information, along with additional statistical analyses discussed later. To ensure correct accuracy calculations, the accuracy of each point was cross-checked using the measuring tool in ArcGIS. On all occasions, the calculated accuracy and the distance measurement in GIS were equal to the nearest hundredth centimeter.

Results

Survey Marker Accuracy

The accuracy for each survey marker and collection time was calculated using the aforementioned formula and descriptive statistics (mean, standard deviation, range, and 95% confidence interval) were determined using SPSS Version 20 for comparison purposes (Table 2). The mean accuracy for the tree-covered survey marker (VOLV119) was 42.97 cm and 41.34 cm for the 50-second and 100-second collection times, respectively. Additionally, the mean accuracy for the survey marker near a tall structure (90501006) was 39.20 cm and 37.30 cm for the 50-second and 100-second collection times, respectively.

The two survey markers in open areas (90501007 and 90501004) showed similar results for both collection times. Survey marker 90501007 demonstrated a accuracy mean of 9.59 cm for 100-second collection time and 11.55 cm for 50-second collection time. Correspondingly, survey marker 90501004 displayed a mean accuracy of 9.51 cm for 100-second collection time and 11.48 cm for 50-second collection time. Therefore, the data collected at survey markers in open areas for both collection times were more accurate than the data collected in obstructed environments, with a mean accuracy of approximately 12.0 cm for 50-second collection time and 10.0 cm for 100-second collection time.

Table 2- Summary of the accuracy results of 50-second and 100-second collection times

Survey marker	**Environment**	**Mean (cm)**	**Standard deviation (cm)**	**Range (cm)**	**95% confidence interval (cm)**
			50-second collection time		
VOLV119	Tree cover	42.97	2.27	39.57 to 46.32	42.08 to 43.86
90501006	Structure	39.20	1.80	34.91 to 42.00	38.50 to 39.91
90501007	Open	11.55	1.65	9.13 to 13.38	10.89 to 12.21
90501004	Open	11.48	1.75	7.98 to 14.79	10.80 to 12.16
			100-second collection time		
VOLV119	Tree cover	41.34	2.87	37.08 to 46.24	40.22 to 42.47
90501006	Structure	37.30	1.95	34.85 to 42.62	36.54 to 38.06
90501007	Open	9.59	1.82	7.36 to 12.84	8.86 to 10.32
90501004	Open	9.51	2.25	5.30 to 13.87	8.63 to 10.39

Furthermore, the survey marker under tree cover was found to have the highest standard deviation, and, thus, demonstrated the most variance of the collected points for both collection times (Table 3). Table 3 shows both the mean accuracy for each survey marker using 50-second and 100-second collection times and the difference between these values, demonstrating that, for all environments, the 100-second collection time was slightly more accurate by approximately 2.0 cm consistently (Table 3). Additionally, Table 4 demonstrates the mean northing and eastings for the survey markers using both collection times, showing that the collected northings were constantly more accurate than the eastings for both collection times and all survey markers.

Table 3- Average error and difference between collection time error of collected points to survey markers

Survey marker	**Environment**	**Mean 50-second error (cm)**	**Mean 100-second error (cm)**	**Mean error difference (cm)**
VOLV119	Tree cover	42.97	41.34	1.63
90501006	Structure	39.20	37.30	1.90
90501007	Open	11.55	9.59	1.96
90501004	Open	11.48	9.51	1.97

Table 4- Mean error of northings and eastings for collected points of survey markers

		50-second		**100-second**	
Survey marker	**Environment**	**Northing (cm)**	**Easting (cm)**	**Northing (cm)**	**Easting (cm)**
VOLV119	Tree cover	23.51	35.92	22.04	34.90
90501006	Structure	21.26	32.88	20.53	30.10
90501007	Open	6.37	9.52	5.33	7.79
90501004	Open	6.40	9.45	5.49	7.56

The results of an independent samples t-test of mean accuracies for the collection times are shown in Table 5. The null hypothesis states that the accuracy of the GPS unit was not significantly affected by the data collection time. The results from this test show that for all survey markers, there was a significant difference in accuracy between 50- and 100-second collection times (VOLV119 $p = .034$, 90501006 $p = .001$, 90501007 $p = .000$, 90501004 $p = .001$). These results support the hypothesis that the accuracy of the DGPS unit was significantly increased by 100-second collection time, compared to 50-second collection time in all environments.

Table 5- Results of independent samples t-test for both collection times and survey markers

Survey marker	**Collection time**	**Mean (cm)**	**s.d. (cm)**	**t**	**df**	***p***
VOLV119 (Tree cover)	50 s	42.97	2.27	2.18	48	*.034*
	100 s	41.34	2.87			
90501006 (Structure)	50 s	39.20	1.80	3.52	48	*.001*
	100 s	37.30	1.95			
90501007 (Open)	50 s	11.55	1.65	3.83	46	*.000*
	100 s	9.59	1.82			
90501004 (Open)	50 s	11.48	1.75	3.47	48	*.001*
	100 s	9.51	2.25			

When considering data collected in open areas, there was an approximate 20% accuracy increase using 100-second data collection when compared to 50-second data collection (Table 6). Table 6 shows the results of the independent samples t-test conducted between the different collection times for both survey markers in open areas. The analysis indicates that the different open areas did not yield significantly different GPS coordinates for both 50- and 100-second collection times (50-second $p = .884$, 100-second $p = .893$), suggesting that the DGPS unit produced consistent results during data collection of the open areas for both collection times.

Table 6- Independent samples t-test of mean error (cm) for 50-second and 100-second collection times and mean percentage changes between collection times for open areas

Collection time	**90501007**	**90501004**	**t**	**df**	***p***
50-second	11.55	11.48	-.146	47	*.884*
100-second	9.59	9.51	-.136	47	*.893*
% change	20.7%	20.4%			

Distance Measurements

The actual maximum length of each long bone was compared to the measurements between collected points in ArcGIS for both 50-second and 100-second collection times. Figure 12 illustrates the points collected at the proximal and distal aspects of the long bones in the field for both collection times in an open area. Lines were added in ArcGIS to illustrate the orientation of the long bones. Overall, the 100-second collection time was consistently more accurate than the 50-second collection time when collected points were compared to actual lengths (Table 7). The range of the positional error was 0.1 cm to 2.8 cm for the 100-second collection time and .5 cm to 5.5 cm for the 50-second collection time (Table 7). Long bones with a maximum length greater than 25 cm demonstrated collected points that were closer to the actual maximum length. Additionally, the orientation of long bones with a maximum length greater than 25 cm demonstrated correct orientation and less varied orientation between collection times when compared shorter long bones (Figure 12).

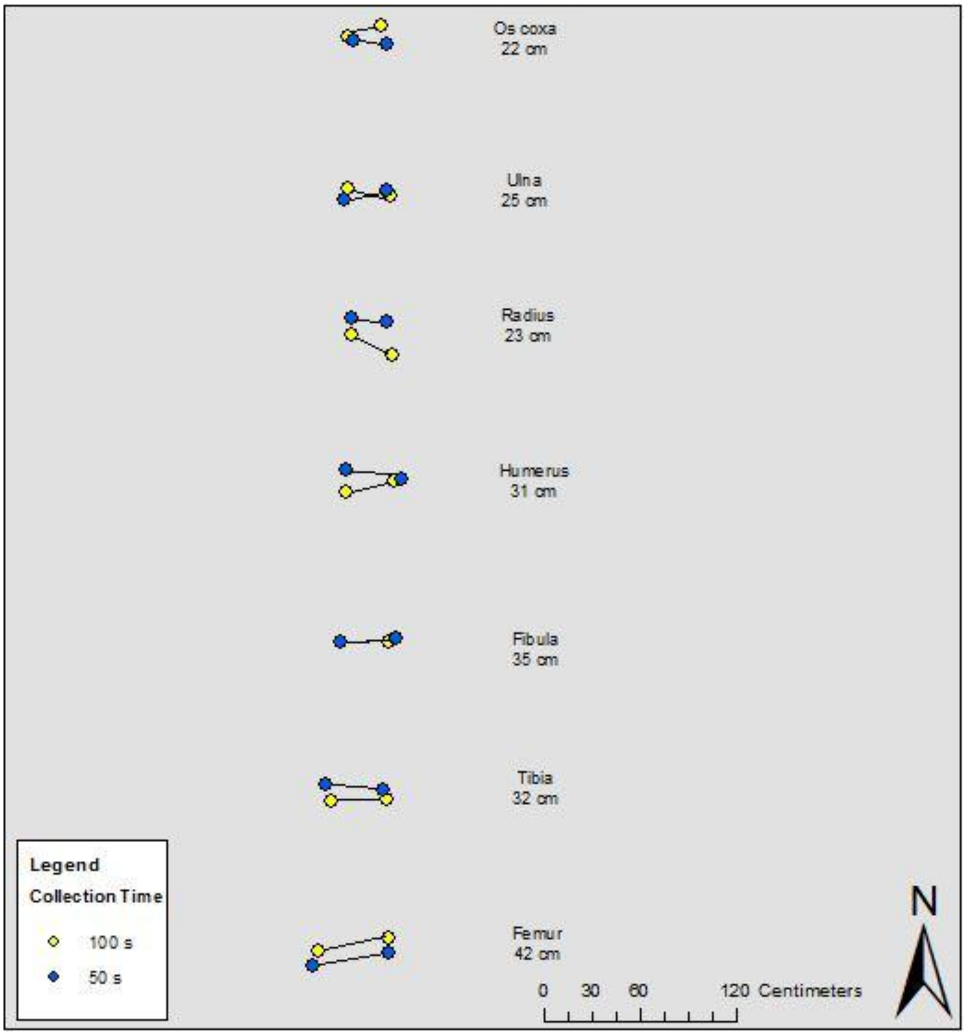

Figure 12- Map of long bone measurements for both collection times

Table 7- Comparison of actual long bone length and lengths between collected points measured in GIS for 50-second and 100-second collection times

	Actual max length (cm)	**GIS max length (cm)**		**Difference (cm)**	
		50 s	100 s	50 s	100 s
Humerus	31.0	35.5	31.8	4.5	0.8
Radius	23.0	21.4	25.2	1.6	2.2
Ulna	25.0	28.5	27.8	3.5	2.8
Femur	42.0	47.5	44.4	5.5	2.4
Tibia	32.0	34.4	33.4	2.4	1.4
Fibula	35.0	37.1	34.3	2.1	0.7
Os coxa	22.0	21.5	22.1	0.5	0.1
		Mean difference		2.9	1.5

Positional data was also collected for known distances (0 cm, 5 cm, 10 cm, 20 cm, 25 cm, and 30 cm) and compared in ArcGIS using the measurement tool. Figure 13 illustrates the collected points at the marked distances with a line symbolizing the measuring tape used in the field to mark the distances. Like the long bone measurements, the 100-second collection time was consistently more accurate than the 50-second collection time, but not by more than 2 cm (Table 8). The range of the positional error was .6 cm to 2.3 cm for the 100-second collection time and 1.1 cm to 2.6 cm for the 50-second collection time (Table 8). Additionally, the error decreased as the distances increased.

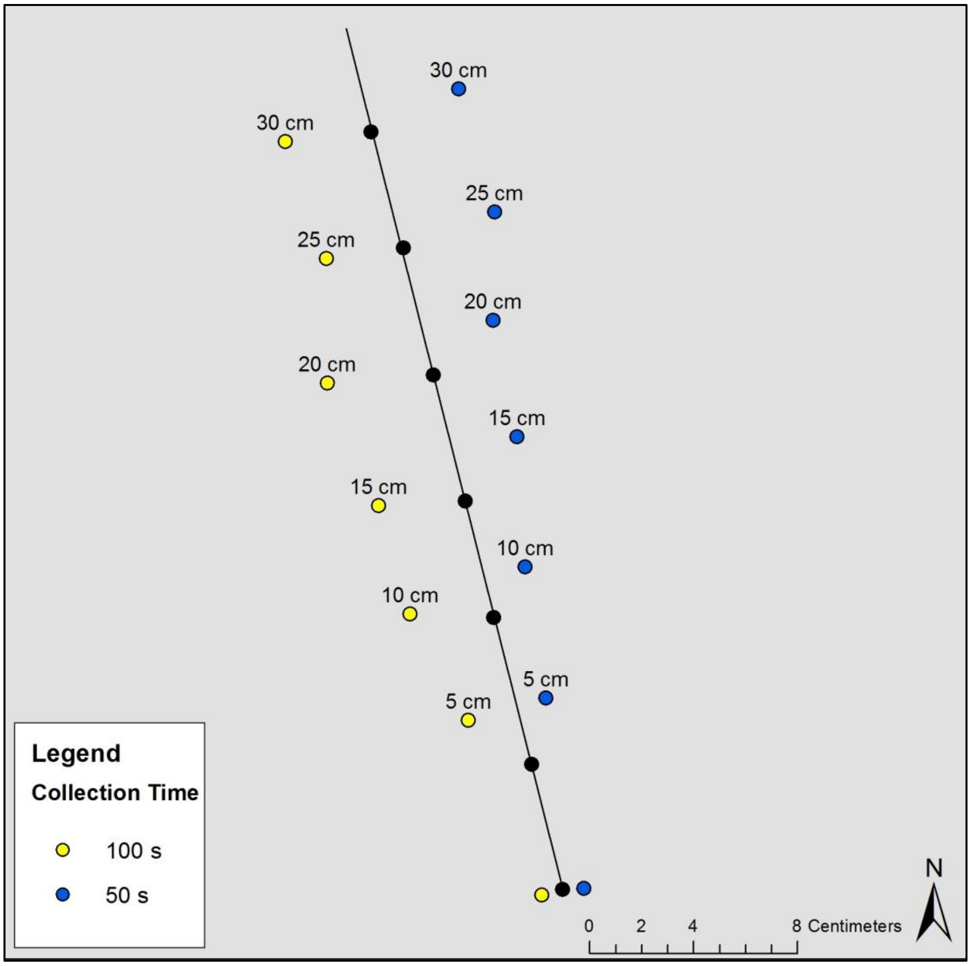

Figure 13- Map of distance measurements for both collection times with tape measure reference and marked intervals

Table 8- Comparison of known lengths and lengths of collected points measured in GIS for 50-second and 100-second collection times

	GIS length (cm)		**Difference (cm)**	
	50 s	100 s	50 s	100 s
5 cm	7.5	7.3	2.5	2.3
10 cm	12.6	11.9	2.6	1.9
15 cm	17.6	16.2	2.6	1.2
20 cm	22.2	21.4	2.2	1.4
25 cm	26.4	25.9	1.4	0.9
30 cm	31.1	30.6	1.1	0.6

Discussion

Similar results among these environments with increased error from older DGPS models can be found in an earlier study by Sando et al. (2005). The accuracy of this DGPS unit in obstructed areas, such as areas under tree-cover and near tall structures, may not be sufficient for mapping skeletal dispersals because of the high level of error. However, open areas produced consistently accurate positional error data for both collection times for two different unobstructed areas and may be considered for mapping purposes.

In 2001, Graettinger et al. reported that observed accuracies in their study on GPS receiver accuracy were significantly higher than the accuracies reported by the manufacturers in the information provided for their product. The DGPS unit used for this study, however, was consistent with the manufacturer's reported accuracy of 10 to 30 cm. Perhaps because accuracy, along with ease of use, of DGPS units is a concern for most consumers, DGPS retailers, such as Trimble, are conducting more in-depth accuracy determination for newer DGPS units.

Furthermore, several factors not considered in previous studies (Listi et al., 2007 and Spradley et al., 2011) were investigated in this chapter, such as data collection methods and accuracy determination in different environments. By considering data collection methods of long bones and clustered skeletal elements, it was determined that long bones less than 25 cm in length should be measured using 2 points and clustered skeletal elements more than 25 cm apart should be measured as separate features. Additionally, the effect of the environment on the accuracy of DGPS units was also considered by determining the error at known survey points in obstructed environments in addition to open areas.

Survey Marker Accuracy

The accuracy calculated from the survey markers in open areas for both collection times, demonstrating that the DGPS used for this research produces relatively consistent results at different locations and on different days when in the same environment. When considering the placement of the collected points, the points tended to cluster northwest of the survey marker for all environments and both collection times (Figures 14 and 15). Additionally, the northings (vertical positions) were less accurate than the eastings (horizontal positions), greatly increasing the calculated error. Spradley et al. also found this to be the case for their point data and attributed this trend to be a "well-known limitation of GPS technology" (Spradley et al., 2011:7); however, no literature could be found concerning this trend.

Figure 14- Composite map of collected points and survey markers for 50-second collection time in Deland, FL

Figure 15- Composite map of collected points and survey markers for 100-second collection time in Deland, FL

The independent samples t-test of the survey markers at different collection times demonstrates that the 100-second collection time yielded significantly different accuracy values than the 50-second collection times. This is expected, as the position of the feature collected is an average of each position collected at 1-second intervals for the duration of the collection time.

Therefore, if time permits, point data should be collected for a minimum of 100 seconds to ensure increased accuracy.

Furthermore, the use of a rangepole and tripod allowed increased precision of the desired point. In cases where a rangepole is not used (*i.e.* Listi et al., 2007 and Spradley et al., 2011), the unit is placed over the desired point at an approximate height when collecting positional information. This method introduces additional error and can provide inconsistent results. Additionally, the inclusion of a level on the rangepole reinforces the exact location of the desired point, while the tripod holds the unit in place until moved. Finally, the use of an antenna allowed easier access to satellites by extending the height of the unit, increasing the satellite geometry necessary to collect accurate positions and keep the data collector's body from obstructing the satellite signals.

Distance Measurements

Positional information collected at known intervals demonstrated that long bones less than 25 cm in length should be collected with one point (*i.e*. scapulae, ribs, vertebrae, etc.), as bones longer than 25 cm can demonstrate the orientation of the element by using two points; thus, it is recommended that bones longer than 25 cm be collected with two points (*i.e.* crania, long bones, etc.). Predetermined points should be assigned to bones less than 25 cm in length and should be consistent throughout data collection. For example, it is recommended that scapulae be measured at the glenoid fossa and all vertebrae should be measured at the anterior aspect of the body. Furthermore, it is recommended to map bones as individual features when skeletal elements are at least 25 cm apart, and to map clusters of 2 or more bones that are less than 25 cm apart as one feature. The user may then include information in the "Notes" data entry describing the skeletal elements comprising the cluster.

As seen with the survey marker accuracy, 100-second data collection time was found to be slightly more accurate with a mean difference of 1.5 cm compared to 2.9 cm when comparing long bone lengths. If time permits, it is best to measure all points with a 100-second collection time, rather than 50-second collection time. However, all points should be recorded consistently with the same collection time, whether it is 50-second, 100-second, or any other time allotment.

Conclusions

This chapter presents a quantification of the influence of different factors likely to affect the accuracy of a DGPS receiver used in the collection of positional data. The accuracy of the DGPS unit was determined in 3 different environments: an open area, a tree-covered area, and an area near a tall structure. Two different collections times, 50-second and 100-second, were conducted within the differing environments. When comparing the collection times, it was determined that the 100-second collection time was slightly more accurate (approximately 20%) than the 50-second collection time. Thus, if time permits, point data should be collected at 100-second time intervals to insure accurate positional information. However, the difference found between the collection times is minimal when considering the error introduced by the environment in obstructed environments.

Additionally, it was determined in this research that the Trimble GeoExplorer 2008 Series DGPS receiver was greatly affected by obstructions within the environment. This unit was accurate to approximately 11.52 cm in open areas, 42.97 cm in areas under tree-cover, and 39.20 cm in areas near a tall structure with a 50-second collection time and 9.55 cm in open areas, 41.34 cm in areas under tree-cover, and 37.30 cm in areas near a tall structure with a 100-second collection time.

Further research is necessary to determine the influence of additional factors to the accuracy of DGPS units such as level of cloud cover, degree of tree-cover, direction of the receiver, time of day, PDOP, and additional collection times. In addition to postprocessing, real-time differential processing should also be investigated. Furthermore, error levels should be determined for additional DGPS units, as only a single DGPS unit was considered in this study.

With the inevitable creation of innovative DGPS technology, increased accuracy of DGPS receivers is an endeavor that should be expected in years to come (Lechner and Baumann, 2000). Studies conducted 7 years ago, show error levels of 1.7 m for DGPS units in open environments (Sando et al., 2005), clearly showing the rapid pace at which DGPS technology is developing when compared to the decimeter accuracy determined from this project. It is, thus, the responsibility of the researcher to evaluate the use of these new technologies in the field within different environments and conditions before applying them in forensic situations.

The following chapter will apply the determined accuracy of the Trimble GeoExplorer 2008 Series DGPS unit calculated in this chapter to simulated scenarios within differing environments and levels of scatter. The assembled scenarios will be analyzed in ArcGIS to determine the applicability of mapping these scenarios using this DGPS unit.

CHAPTER THREE: MAPPING SIMULATED SKELETAL DISPERSALS USING A DGPS UNIT

Introduction

Until recently, GPS units have been used only to collect basic GPS coordinates, such as datums, rather than the specific location of remains within archaeological sites (Napton and Greathouse, 2009). Surveying methods using DGPS units have been conducted archaeologically for several years. DGPS units have been used to survey both large and small archaeological sites all over the world. An ancient road network in Armana, Egypt with a total of 70 roads has been mapped using a DGPS unit (Fenwick, 2001). Several times surveys have been conducted using a DGPS unit to create digital elevation models (DEM) of archaeological sites (Chapman and Van Nort, 2001; Fenwick, 2001). Collier et al. (1995) utilized a DGPS to construct a large triangle irregular network (TIN) for spatial analysis at an archaeological project in Langstone Harbor, England. Also, digital terrain models (DTM) have been created using GPS data (Capra et al., 2002). Additionally, DGPS data collected at archaeological sites can be used not only for surveying purposes but also in several kinds of spatial analyses such as the relationship between elevation, landscape, feature locations, artifact dispersal patterns.

Listi et al. (2003) presented the first research concerning GPS as a utility in mapping skeletal dispersals in a poster presentation at the American Academy of Forensic Sciences. It was determined through this preliminary study that the use of a GPS unit with beacon receiver was only a valuable tool in scene mapping for pinpointing the location of the entire scene or a datum rather than mapping individual skeletal elements.

As discussed in the previous chapter, limited research has been conducted concerning the utility of a DGPS unit in mapping skeletal dispersals. Other than Listi et al.'s (2003) preliminary research, two studies have been published that utilize a DGPS in mapping human remains Listi et al. (2007) and Spradley et al. (2011). However, though Spradley et al. (2011) utilize a DGPS for scene mapping, their research was primarily focused on the analysis of scavenging patterns from vultures on a human cadaver and not the development of a methodology concerning mapping using a DGPS.

In both studies, the type of dispersal (*i.e.* wide scatter versus tight scatter) was not a consideration by the authors. Additionally, both environments in these studies were mixed environments with skeletal elements scattered in both open and obstructed environments. Most importantly, the error values determined by Listi et al. (2007) were calculated from a survey marker in an open environment and were applied to open and wooded environments. Moreover, the determined accuracy using 206-second collection time was inappropriately applied to data collected in various environments at 100-second collection times.

Furthermore, the single simulated scenario constructed by Listi et al. consisted of only 8 features and the skeletal dispersal assessed by Spradley et al. (2011) included only one scenario. Thus, further research with multiple environmental scenarios and dispersal levels must be conducted to accurately assess the practicality of using these enhanced DGPS units in mapping skeletal dispersals.

Purpose

The purpose of this chapter is to determine the applicability and practicality of utilizing a DGPS unit in mapping skeletal dispersals. Environments such as open areas, areas under tree-cover and areas near a tall structure will be considered. In addition, the distribution of the skeleton, such as widely scattered, tightly scattered, and relatively articulated dispersals, will also be considered. The calculated accuracy of the DGPS in the different environments from the previous chapter will be applied to these scenarios as well. Because the DGPS is a relatively new technology that has yet to be comprehensively utilized in the mapping of human remains, different aspects of this utility, such as data collection time, data collected on different days, proximity of features, feature collection, postprocessing methods and attribute data collection, will also be demonstrated.

Differential Global Positioning System and Scene Mapping

In situations where scattered remains are extensively dispersed over a large area or topographically varied area, standard mapping techniques can be a difficult task (Listi et al., 2007; Napton and Greathouse, 2009). Differential GPS receivers can be easily moved to each skeletal element over a large area, without introducing additional error as a result of long-distance measuring. Furthermore, GPS geospatial data can also be integrated into a GIS which allows the user to analyze and effectively display the mapped scene (Lowe and Burns, 1998; Gao, 2002; Spencer et al., 2003; El-Rabbany, 2006; Dupras et al., 2011).

Additionally, DGPS software allows the recordation of attribute data for features through preset data dictionaries, such as bone type and side that can later be accessed in a GIS using an attribute table (Trimble Navigation Limited, 2009). The user may then label the map in GIS with this information for presentation purposes. Furthermore, distance between points can be easily calculated by using a measuring tool (Wheatley and Gillings, 2002). These features may be useful in a court setting where the distance between bones and scene features can be easily determined while testifying, and an inventory of the remains or associated evidence can be referenced.

Materials and Methods

As in the previous chapter, the differential GPS used for this research was a Trimble GeoExplorer 2008 Series GeoXH handheld differential GPS receiver with Zephyr antenna. The receiver uses a field computer powered by Microsoft Windows Version 6 operating system and Terrasync software. The receiver uses both H-star and EVEREST multipath technology to provide heightened accuracy after postprocessing using the internal antenna. The addition of the external Zephyr antennae provides better locational recordation with 10 cm to 30 cm accuracy when data is differentially postprocessed (Trimble Navigation Limited, 2009).

Scenarios

Scenarios were constructed to depict various levels of skeletal dispersals that may be encountered in real-life situations. The following levels of dispersals were considered: wide scatters, tight scatters, and relatively articulated scatters (Table 9). Additionally, the following environments were considered: open areas, tree-covered areas, and areas near tall structures (Table 9).

The environments in this research were chosen to represent three types of outdoor environments that dumped human remains are found. Manhein et al. (2008) found that human remains are dumped in both open and wooded environments or within sight of a structure. Furthermore, the different levels of dispersals were chosen to represent dispersal scenarios of human remains in outdoor settings. Skeletal dispersals have been known to range from relatively articulated skeletons to skeletal elements dispersed over hundreds of meters in rural areas (Manhein et al., 2008).

Table 9- Summary of types of dispersals and environments considered for the simulated scenarios

Type of Dispersal	**Environment**
Wide Scatter	Open area
Tight scatter	Tree-covered area
Relatively articulated skeleton	Area near structure

The simulated scenarios were determined by combining each environment with each type of dispersal for a total of nine scenarios (Table 10). Point data were collected with different 50-second and 100-second collection times for all scenarios. Also, offsets and increased productivity settings were implemented in obstructed environments.

Table 10- Summary table of the simulated scenarios with environment, type of dispersal, and variables considered during data collection

Scenario #	Environment	Type of dispersal	Variables considered
1	Open area	Wide scatter	• Collection time • Postprocessing • Different days
2	Tree-covered area	Wide scatter	• Collection time • Offsets • Productivity settings
3	Open area	Tight scatter	• Collection time
4	Tree-covered area	Tight scatter	• Collection time • Offsets • Productivity settings
5	Open area	Relatively articulated skeleton	• Collection time
6	Tree-covered area	Relatively articulated skeleton	• Collection time • Offsets • Productivity settings
7	Area near structure	Wide scatter	• Collection time • Offsets • Productivity settings
8	Area near structure	Tight scatter	• Collection time • Offsets • Productivity settings
9	Area near structure	Relatively articulated skeleton	• Collection time • Offsets • Productivity settings

Three areas were chosen to represent the predetermined scenario environments on the University of Central Florida campus (Figure 16). The open area was a cleared area in the University of Central Florida Arboretum. The tree-covered area was also an area in the Arboretum but was densely covered with trees. Finally, the scenarios near a tall structure were conducted in an urban area on the University of Central Florida's campus which was located on the south aspect of Howard Philips Hall.

Figure 16- Aerial image of the scenario locations on the University of Central Florida campus

Data Collection

Prior to the day of data collection, planning almanac software (available through Trimble) was consulted to determine the best time for data collection. This software provides information including the satellite position data, DOP data, and elevation data on specific days (Figure 17). The best time for data collection was determined by considering the greatest number of satellites, with at least 4 satellites being the most desirable, and the least PDOP value, with values less than 2 being the most desirable (Johnson and Barton, 2004; Bolstad, 2005). Data collection was then conducted during this time period if weather permitted. See Appendix B for planning information for each day of data collection.

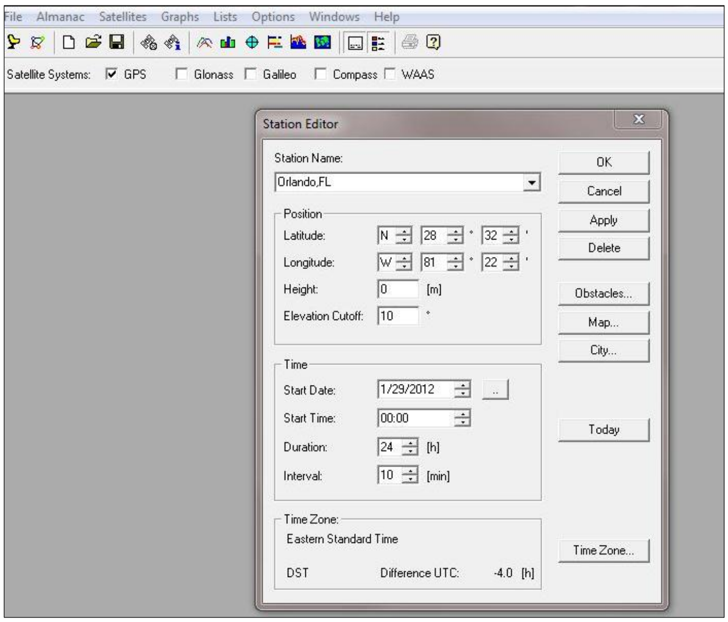

Figure 17- Screenshot of planning using Trimble Planning Software

In addition to planning the best time of day for data collection the orientation of the DGPS receiver was also considered. Vertical orientation of the GPS receiver has been found to significantly influence accuracy, with vertical orientation of the receiver yielding coordinates that are more accurate when compared to horizontal orientation (Sando et al., 2005). Data were collected in Universal Transverse Mercator (UTM), Zone 17 North, with the WGS 1984 datum. The rangepole served as the anchor during data collection. The end of the rangepole was positioned at predetermined point adjacent to the skeletal element on the ground and was then leveled using the dot level on the tripod (Figure 18). The rangepole remained stationary throughout the data collection time.

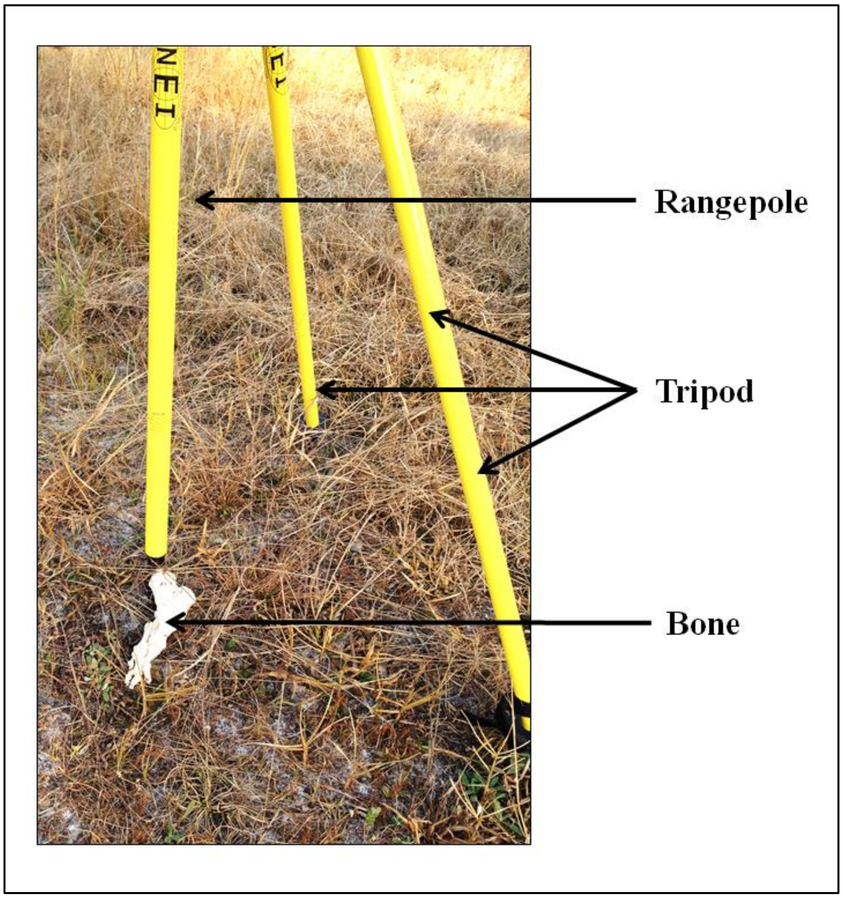

Figure 18- Image of rangepole placement during data collection with labeled components

Point data were collected using the batch method, which is the average of the point data in 1-second intervals. For example, a batch reading for a point collected at 1-second intervals for 50 seconds would yield the average of 50 points collected at that location. The collection times chosen for this research were chosen in accordance with the 100-second collection time used in previous research (Listi et al., 2007) with the addition of the more efficient 50-second collection time for comparison purposes.

The following information was recorded during point data collection:

- Date
- Time
- Northing
- Easting
- Max HDOP
- Max PDOP
- Correction Type
- Receiver Type
- Filtered and unfiltered positions
- Feature Name (*i.e.* bone)
- Data dictionary used
- Filename

Point data were collected at each point of interest in 1-second intervals for 50 seconds and 100 seconds. Fifty-second and 100-second data were collected on the same day, consecutively.

The distance analysis conducted in Chapter 2 was implemented during data collection by collecting data for bones with a maximum length of less than 25 cm as a single point, and with a maximum length exceeding 25 cm as two points at opposite aspects (*i.e.* proximal and distal ends) (Table 11). Furthermore, skeletal elements clustered within 25 cm of each other were recorded as a single feature.

Table 11- Description of points and number of points collected on bones and number of points collected for each skeletal element

Skeletal element	Number of Points	Description of points collected
Cranium	2	If oriented sideways: anterior and posterior aspects If oriented longways: superior and inferior aspects
Mandible	1	Anterior aspect
Vertebrae	1	Anterior aspect of the body
Sternum	2	Superior and inferior aspect
Ribs	1	Medial aspect of head
Scapulae	1	Lateral aspect (glenoid fossa)
Clavicle	1	Anterior aspect of midshaft
Os coxa	2	Superior and inferior aspects
Humerus	2	Proximal and distal aspects
Radius	2	Proximal and distal aspects
Ulna	2	Proximal and distal aspects
Carpal	1	Distal aspect
Metacarpal	1	Distal aspect
Manual phalanx	1	Distal aspect
Articulated hand	2	Proximal and distal aspects
Femur	2	Proximal and distal aspects
Patella	1	Distal aspect
Tibia	2	Proximal and distal aspects
Fibula	2	Proximal and distal aspects
Tarsal	1	Distal aspect
Metatarsal	1	Distal aspect
Pedal phalanx	1	Distal aspect
Articulated foot	2	Proximal and distal aspects

For the scenarios set in obstructed environments (Scenarios 2, 4, 6, 7, 8, and 9), offsets and lowered precision settings were implemented when the satellite geometry was too low for data collection. As discussed in Chapter 2, good satellite geometry is important for accurate data collection and is accomplished by an ideal number and position of satellites overhead. Mid-price DGPS units, such as the GeoXH used for this research, have a slider bar that allows the user to favor productivity instead of precision (Figure 19). Finer precision requires a lower PDOP and, thus, highly favorable satellite geometry (Trimble Navigation Limited, 2009). It is customary when working in areas with interference to increase the productivity, which degrades the precision (Trimble Navigation Limited, 2009). The precision of the unit was lowered until the satellite geometry allowed data to be collected for obstructed skeletal elements and the level of precision was recorded for all skeletal elements that were collected with modified precision.

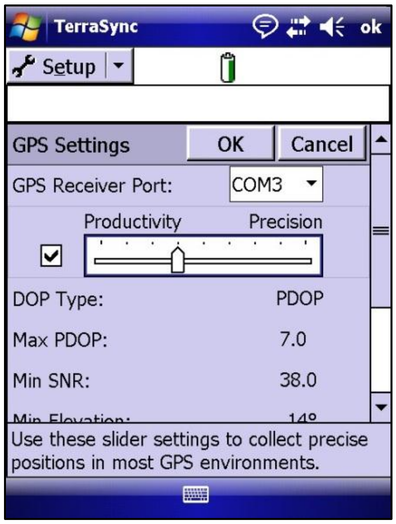

Figure 19- Productivity versus precision feature in Terrasync

Additionally, basic offsets were applied for skeletal elements in areas that were too obstructed for data collection after employing the productivity feature. The DGPS unit was held stationary in an area with good satellite geometry while the bearing and distance were collected and entered into the unit (Figure 20). When collecting a point using an offset, the DGPS unit collects the point data of the DGPS in the unobstructed area, the user then enters the bearing and distance into the information of the feature (Figure 20). During postprocessing, the software takes into account this offset and determines the coordinates of the feature according to the offset information provided by the user (Trimble Navigation Limited, 2009).

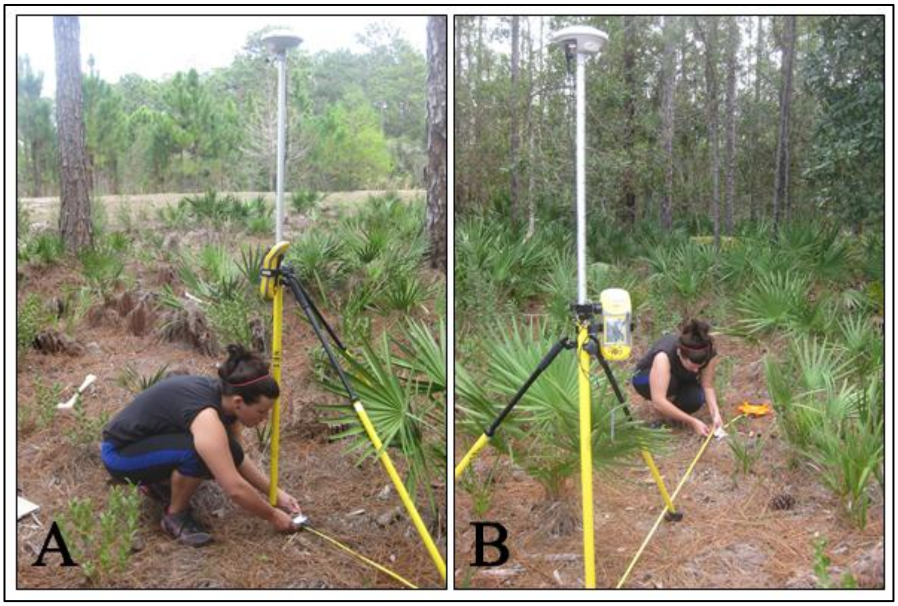

Figure 20- Images of offset use in the field, with (A) bearing measurement and (B) distance measurement

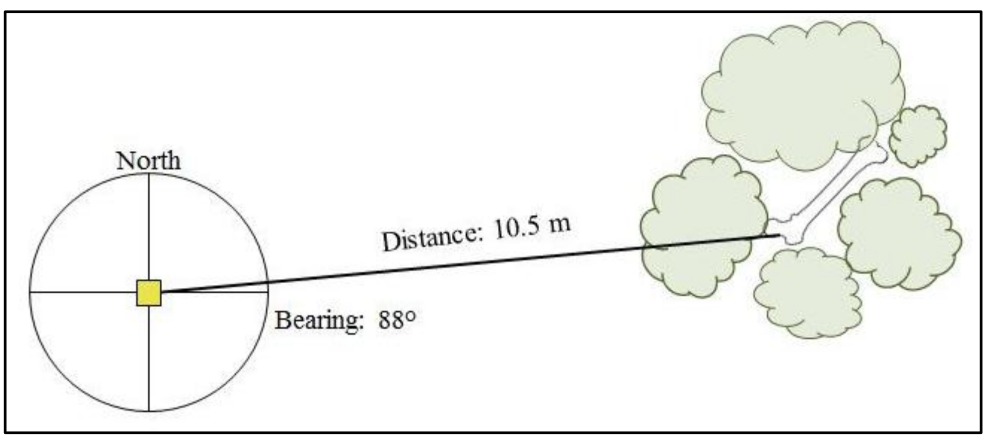

Figure 21- Demonstration of distance and bearing data collection for simple offsets using a DGPS unit

Data were collected using a predefined data dictionary with bone type, bone side, aspect, collection time, and notes (Figure 22). These attributes were later exported into ArcGIS with the point data for analysis and map creation.

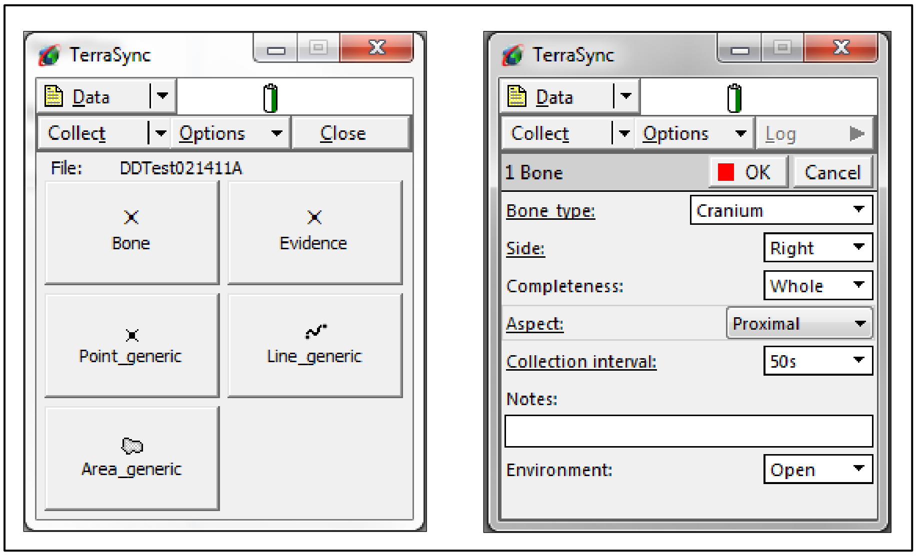

Figure 22- Screenshot of point collection with data dictionary in DGPS unit in Terrasync

Data Processing

After point data were collected in the field, unprocessed data were transferred to a desktop computer using ActiveSync. This data was then imported into Pathfinder Office for differential postprocessing (Figure 23). Postprocessing capabilities refers to the ability of the GPS receiver to store GPS system data in a format that can be used to compute differential corrections of the location data using corrections recorded at a reference receiver to improve locational accuracy (Bolstad, 2005). Uncorrected data were collected in the field and then differentially postprocessed against the closest public basestation in Deland, Florida (CORS96), approximately 51 miles from the mapped area (integrity index = 94.14), using Pathfinder Office.

The integrity index is a grading system by Trimble that monitors basestations used for differential processing and rates a basestation on its reliability, accuracy, and precision (Trimble Navigation Limited, 2004). Additionally, the integrity index value for a basestation is adjusted in consideration of the proximity of the basestation to where the data was collected by the rover unit. Trimble recommends postprocessing against a basestation with an integrity index of 80 or higher and that is within 200 kilometers of the site (Trimble Navigation Limited, 2009). It is important for the basestation to be in close proximity (a maximum of 200 km) of the roving receiver, as this will allow the receiver and basestation to collect data from the same satellite constellation and produce less error during differential postprocessing (Bolstad, 2005). Processed data were then exported into ArcGIS for analysis in ArcMap. The GIS software used for this research was version 10 of ESRI ArcGIS and included the use of ArcCatalog and ArcMap.

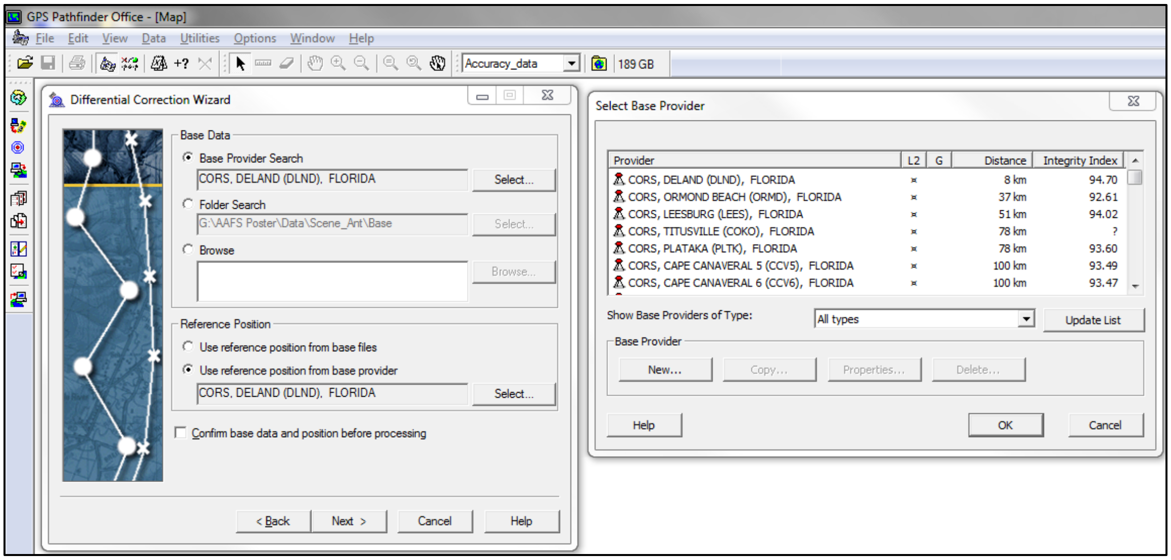

Figure 23- Screenshot of differential postprocessing with basestation selection in ArcCatalog

A geodatabase was created for each scenario to organize the collected data (Figure 24). This was accomplished by creating shapefiles from the exported data and grouping these shapefiles into feature datasets. A shapefile is a filetype used in GIS that is a non-topological digital storage format used to store the geometric location of features on a map and includes collected attribute information (Bolstad 2005; Conolly and Lake, 2006). Additionally, the filetype allows the easy projection change from one coordinate system to another without losing substantial positional information (Bolstad, 2005). For comparison purposes, coordinate data of the survey markers were also imported into the geodatabase as a shapefile using Microsoft Excel and the XY data tool in ArcGIS.

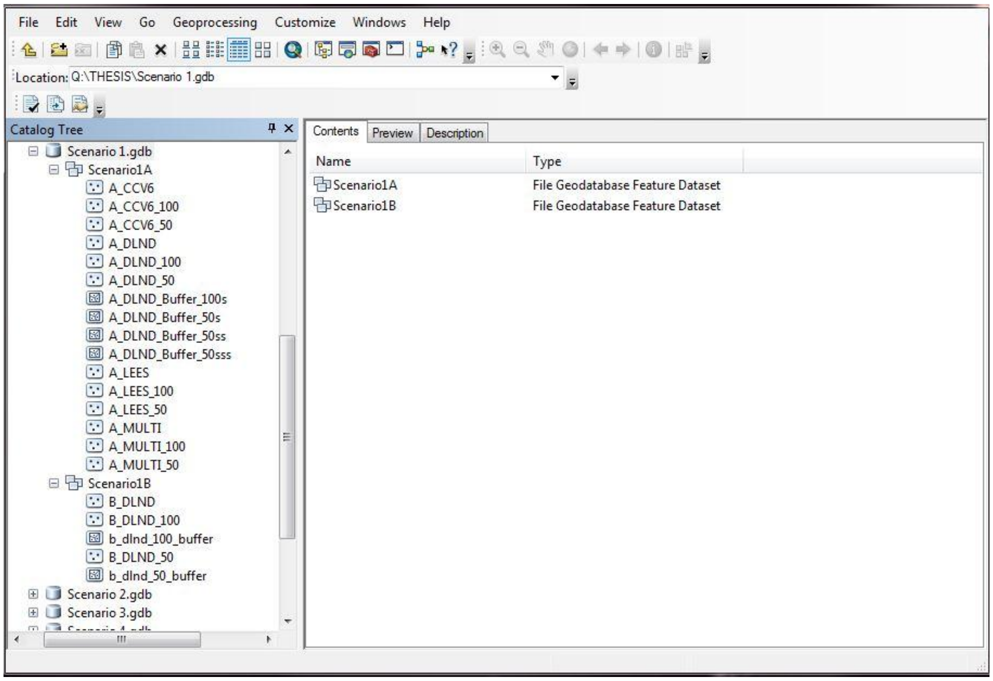

Figure 24- Screenshot of the geodatabase created for the scenarios

These methods were employed for all of the scenarios on different days. The scenarios were then analyzed to determine the practicality of utilizing a DGPS unit in mapping skeletal dispersals.

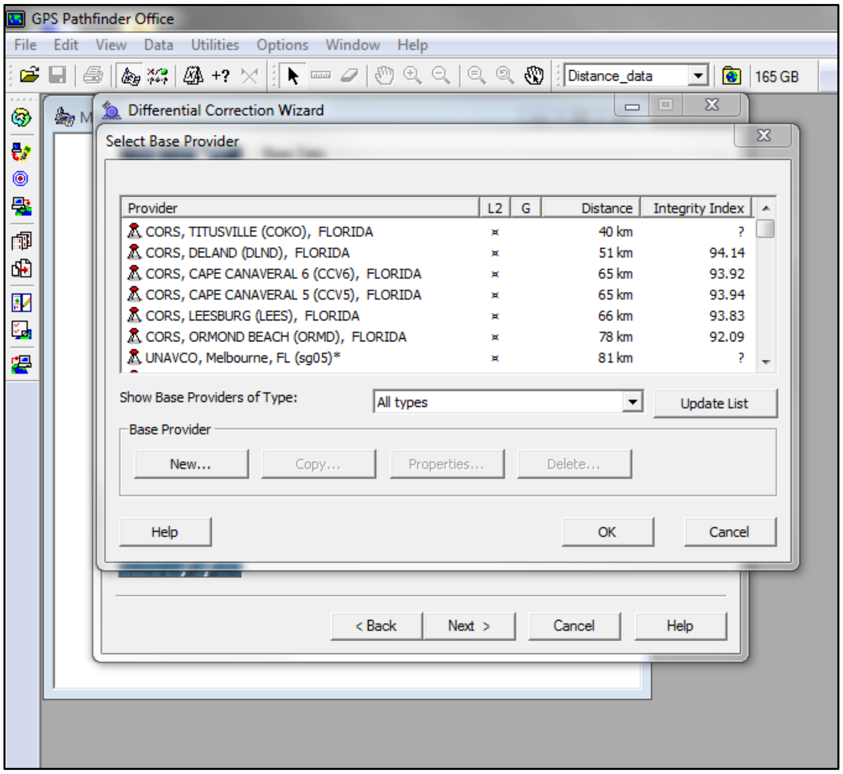

Figure 25- Screenshot of basestation selection during postprocessing in Pathfinder Office

Unlike Scenarios 2 to 9, Scenario 1 underwent additional postprocessing to ascertain the influence of single and multiple basestations for differential correction, along with different basestations at multiple distances from the area of data collection. Scenario 1 was processed using the Deland basestation (DLND), Cape Canaveral basestation (CCV6), and Leesburg basestation (LEES) (Table 12). This scenario was also processed using multiple basestations (DLND, CCV6, and LEES) (Figure 26) and was compared to differential processing of a single basestation (DLND).

Table 12- Basestations used during postprocessing of Scenario 1 with location, distance, and integrity index

Basestation	Location	Distance	Integrity Index
DLND	Deland, FL	51	80.97
CCV6	Cape Canaveral, FL	65	84.98
LEES	Leesburg, FL	66	81.20

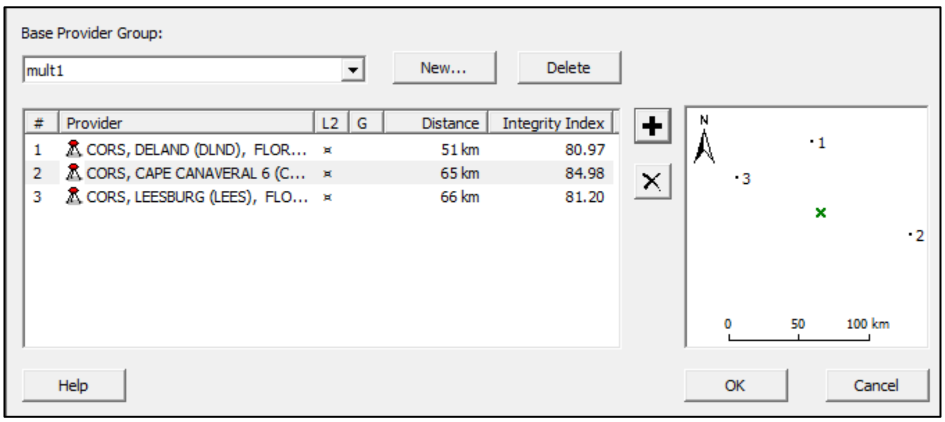

Figure 26- Screenshot of postprocessing with multiple basestations in Pathfinder Office

Processed data were then exported into ArcGIS 10 for analysis in ArcMap. The GIS software used for this research was version 10 of ESRI ArcGIS and included the use of ArcCatalog and ArcMap.

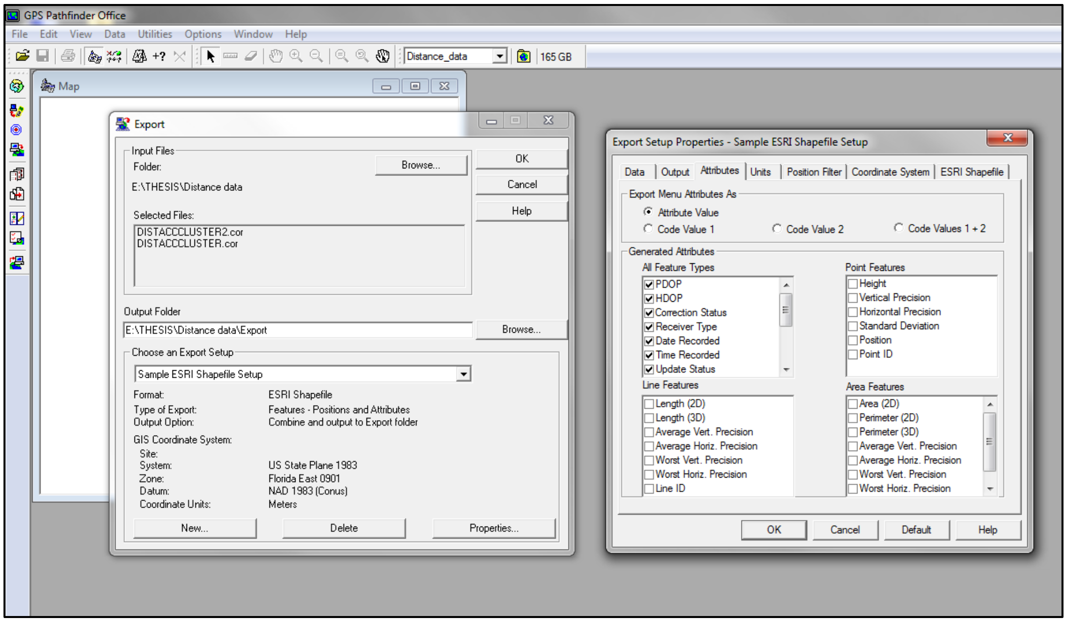

Figure 27- Screenshot of export from Pathfinder Office to ArcGIS

Generating Maps and Integrating Accuracy Data

The mean accuracy of each environment (open area, area under tree-cover, and area near a tall structure) determined in Chapter 2 was applied to each scenario using the buffer tool in ArcMap. A buffer shapefile was created using the buffer tool by inputting the point shapefile and setting the radius to 11.52 cm, 42.97 cm, and 39.20 cm for open areas, tree-covered areas, and areas near a tall structure for 50-second collection times, respectively. A buffer was also created for points collected using a 100-second collection time with radii of 9.53 cm, 41.34 cm, and 37.30 cm for open areas, tree-covered areas, and areas near a tall structure, respectively. The radius for the open area was determined as the mean of the error from both survey markers in open areas for both collection times. By adding this shapefile, one is able to take into account the error of the DGPS for the collected points visually for the scenarios. The individual buffers for each feature were dissolved (Figure28A) to show the overall error for clustered elements and to prevent confusion from interpreting overlapping buffers such as in Figure 28B.

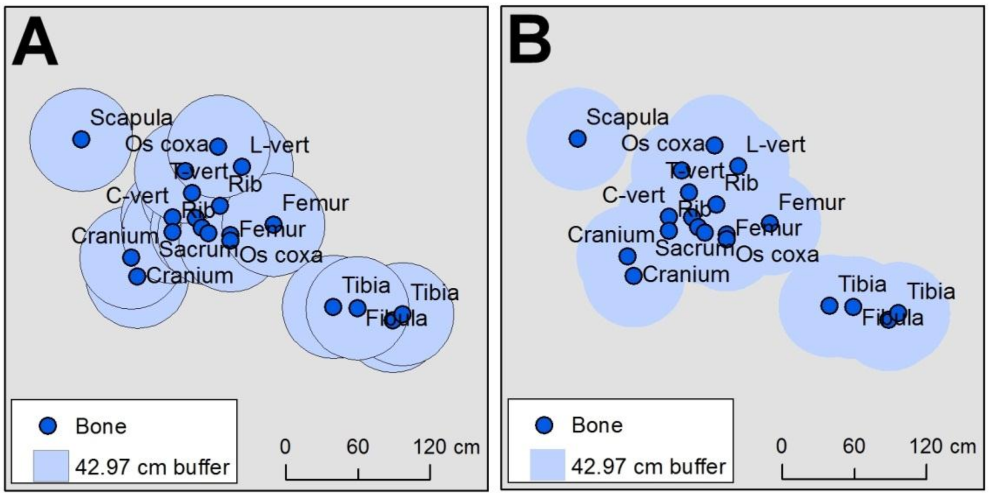

Figure 28- Image from Scenario 4 showing undissolved (A) and dissolved (B) buffers created in ArcMap

Results

Each scenario is displayed separately to independently illustrate the differences of dispersal type and environment with the addition of error buffers. Overall maps for each scenario and collection time with error buffers are displayed in Appendix C.

Scenario 1

Scenario 1 consisted of a wide skeletal dispersal in an open area and was collected using 50-second and 100-second collection times (Figure 29). This scenario was also postprocessed using three different basestations, in addition to being postprocessed against a group of three basestations. Furthermore, the skeletal elements in this scenario were flagged and collected on two different days using the same data collection methods.

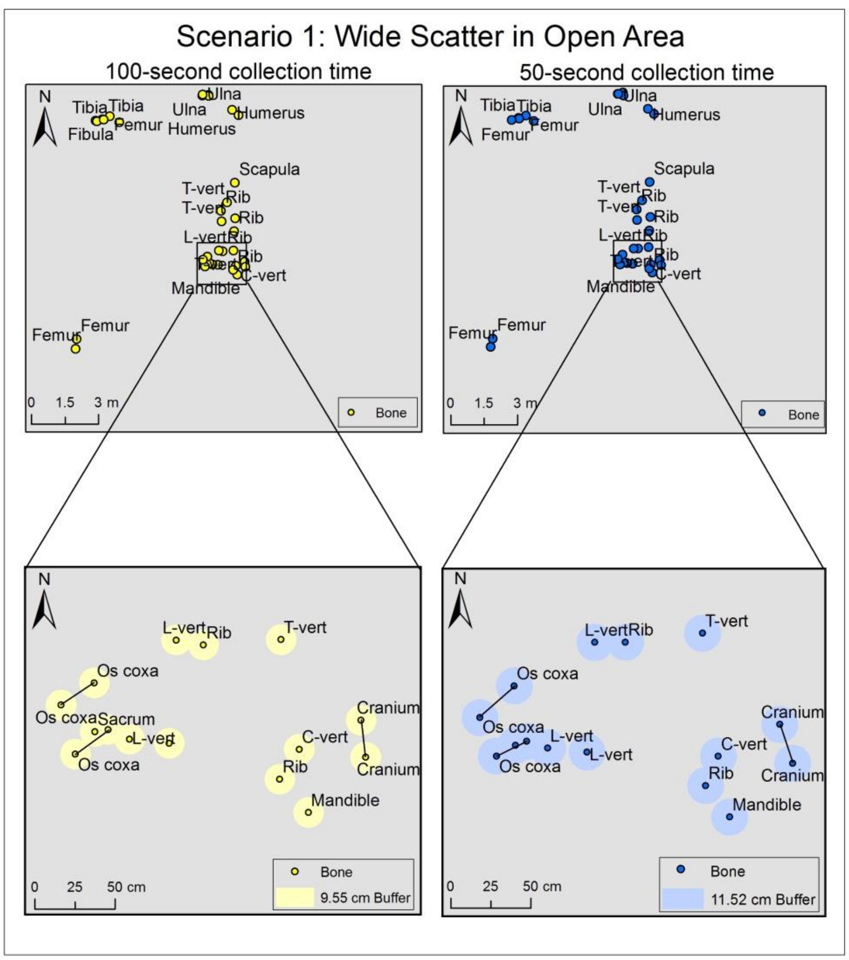

Figure 29- Map of 100-second and 50-second collection times with accuracy buffers of Scenario 1 using ArcMap

Point data were compared in ArcGIS to ascertain orientation and length differences between postprocessed data against different basestations and postprocessed data against multiple basestations for both collection times (Figure 30). The orientation of the long bones was generally maintained for all postprocessed data collected using a 100-seond time collection, while the orientation of the long bones using the 50-second collection time was not as consistent. This trend was also demonstrated when considering the actual length of the long bones, with the data collected using the 100-second collection time collecting a maximum length consistent with the actual maximum length of the long bones. The basestation with the greatest distance from Scenario 1, LEES, produced the most inconsistent orientation and the greatest difference from the actual maximum length of the long bones. This is to be expected, as an increase of distance decreases the reliability of a basestation (Bolstad, 2005). All processed point data, however, fell within error buffers for this environment determined in the previous chapter.

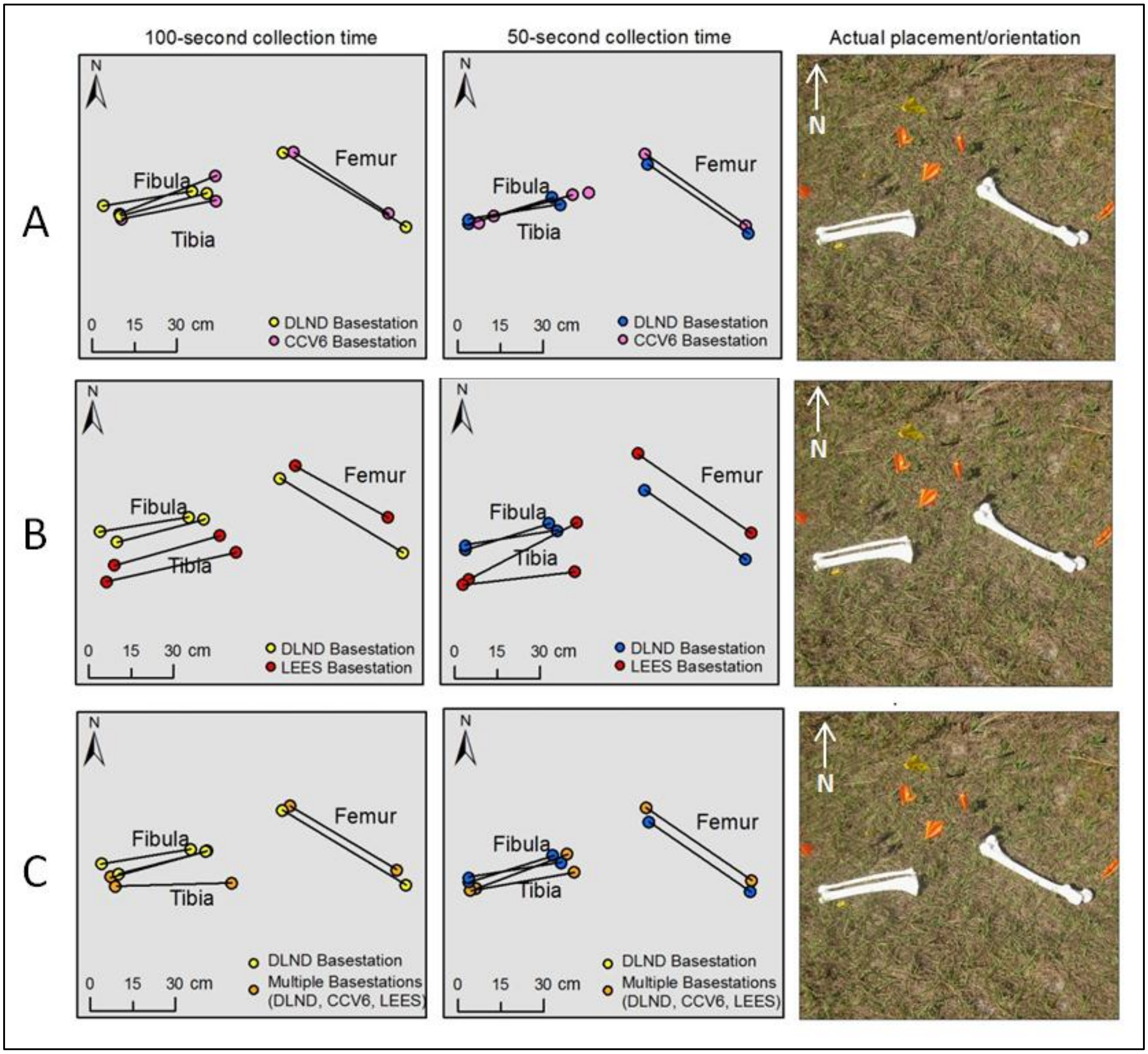

Figure 30- Composite image created using ArcMap of DLND basestation against CCV6 (A), LEES (B), and multiple basestations (C) with actual orientation of long bones in the field

Point data collected on different days for Scenario 1 were postprocessed against the DLND basestation and compared in ArcGIS (Figure 31). The general orientation of the long bones were maintained with both collection times for Day 2 but contrasted slightly from the orientation of the long bones for Day 1. Also, the 100-second collection time recorded maximum lengths closer to the actual maximum lengths of the long bones for both days when compared to the 50-second collection time. The data collected on Day 2 fell within the error buffers determined in the previous chapter for this environment using both collection times.

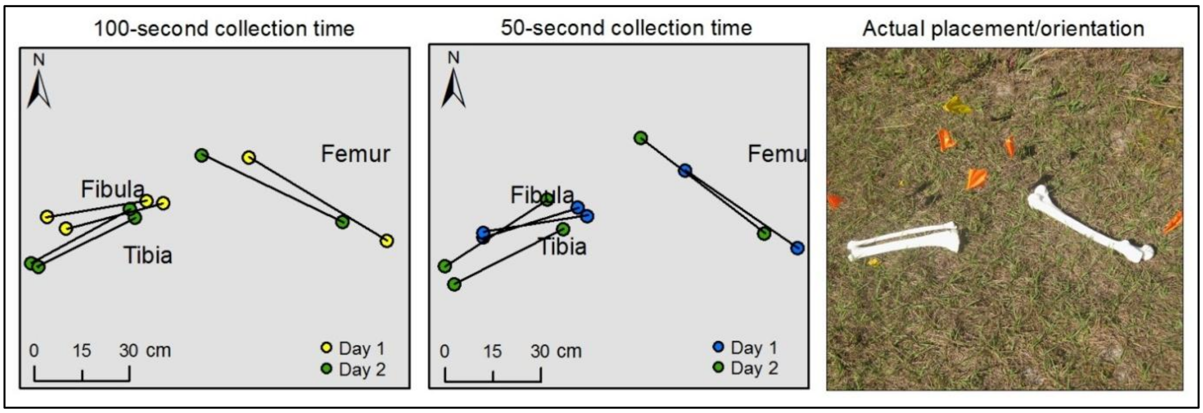

Figure 31- Map of Scenario 1 for 100-second and 50-second collection time on different days using ArcMap

Scenario 2

Scenario 2 consisted of a wide skeletal dispersal in a tree-covered area using 50-second and 100-second collection times. Productivity settings were increased for features in locations that were too obstructed for standard data collection. Offsets were implemented for skeletal elements when locational data could not be obtained using the highest productivity setting. This scenario was differentially corrected against the DLND basestation during postprocessing.

The influence of obstructions on locational data is clearly illustrated in this scenario. The long bones did not maintain maximum length or orientation between the different collection times. Figure 32 shows the change in orientation of the os coxae and the differences in maximum length of the cranium. Additionally, Figure 32 illustrates the problematic overlapping of the error buffers because of the increased error radius calculated for obstructed environments.

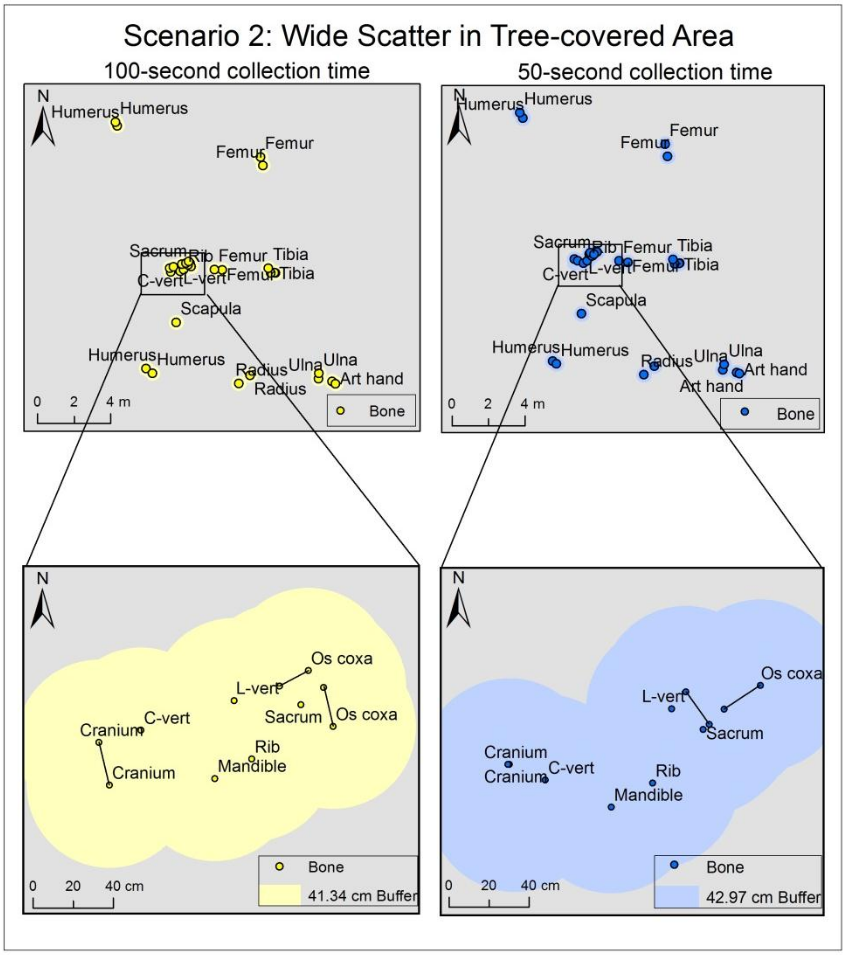

Figure 32- Map of 100-second and 50-second collection times with accuracy buffers of Scenario 2 using ArcMap

Scenario 3

Scenario 3 consisted of a tight skeletal dispersal in an open area using 50-second and 100-second collection times. This scenario was differentially corrected against the DLND basestation during postprocessing. Like the wide scatter in an open area (Scenario 1), increased collection time for point data collected in Scenario 3 maintained the relative orientation and maximum length of the long bones (Figure 33). Also, the decreased radius of the error buffer and dispersal type caused minimal overlapping of the features, resulting in an accurate depiction of the dispersal.

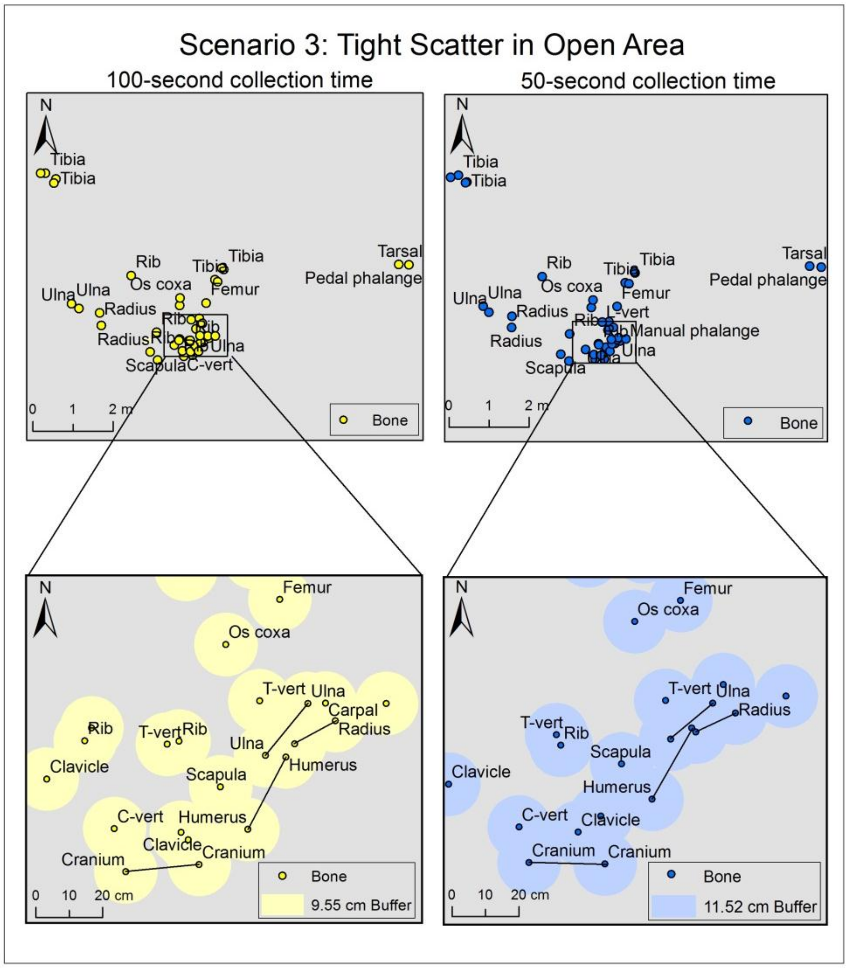

Figure 33- Map of 100-second and 50-second collection times with accuracy buffers for cenario 3 using ArcMap

Scenario 4

Scenario 4 consisted of a tight skeletal dispersal in a tree-covered area using 50-second and 100-second collection times. Productivity settings were increased for features in locations that were too obstructed for standard data collection. Offsets were implemented for skeletal elements when locational data could not be obtained using the highest productivity setting. This scenario was differentially corrected against the DLND basestation during postprocessing.

Scenario 4 produced similar results to Scenario 2, the wide scatter in a tree-covered area, with increased collection time for point data not maintaining the maximum length and orientation of most of the long bones for both collection times (Figure 34). Figure 34 also shows a complete change of direction for the orientation of the right os coxa which is the os coxa near the lower part of the image. Also, the overlap of the clustered features is problematic because of the increased buffer radius for this type of dispersal.

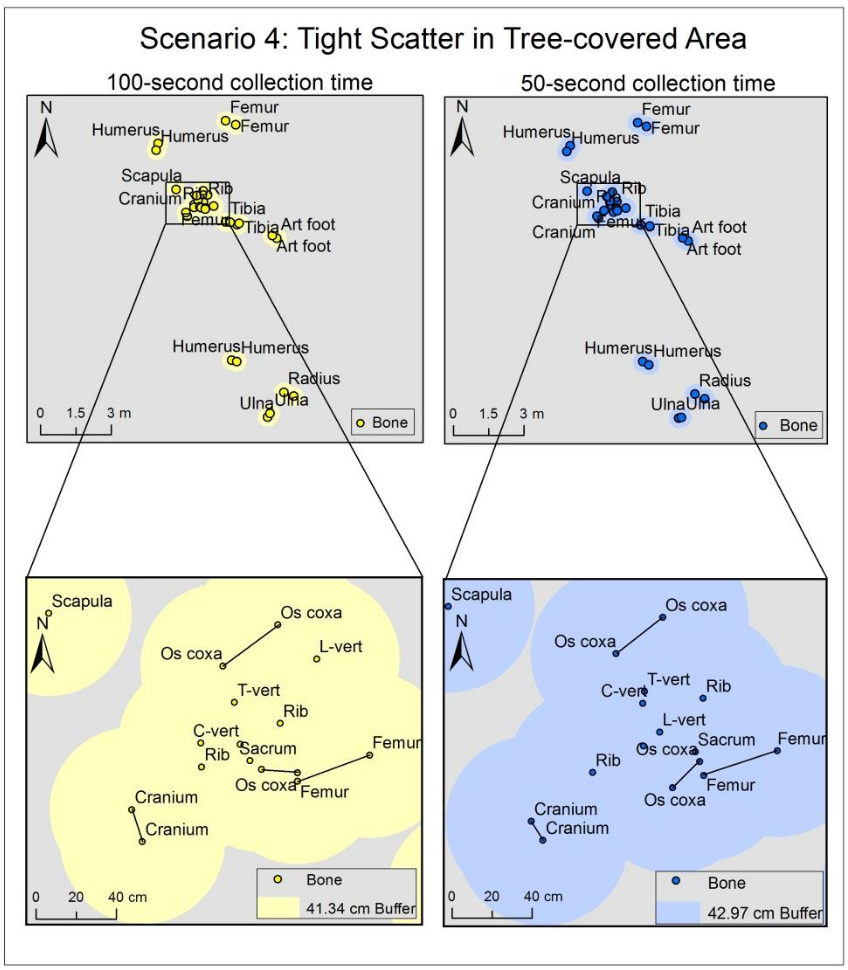

Figure 34- Map of 100-second and 50-second collection times with accuracy buffers of Scenario 4 using ArcMap

Scenario 5

Scenario 5 consisted of a relatively articulated skeleton in an open area using 50-second and 100-second collection times. This scenario was differentially corrected against the DLND basestation during postprocessing. Increased collection time for point data collected in this scenario shows preservation of the general orientation and maximum length of the long bones (Figure 35). Some single features, however, did not maintain an exact position but fell within the error buffer. Furthermore, increased overlapping of the error buffers when compared to the other scenarios in open areas (Scenarios 1 and 3) was noted for this type of dispersal.

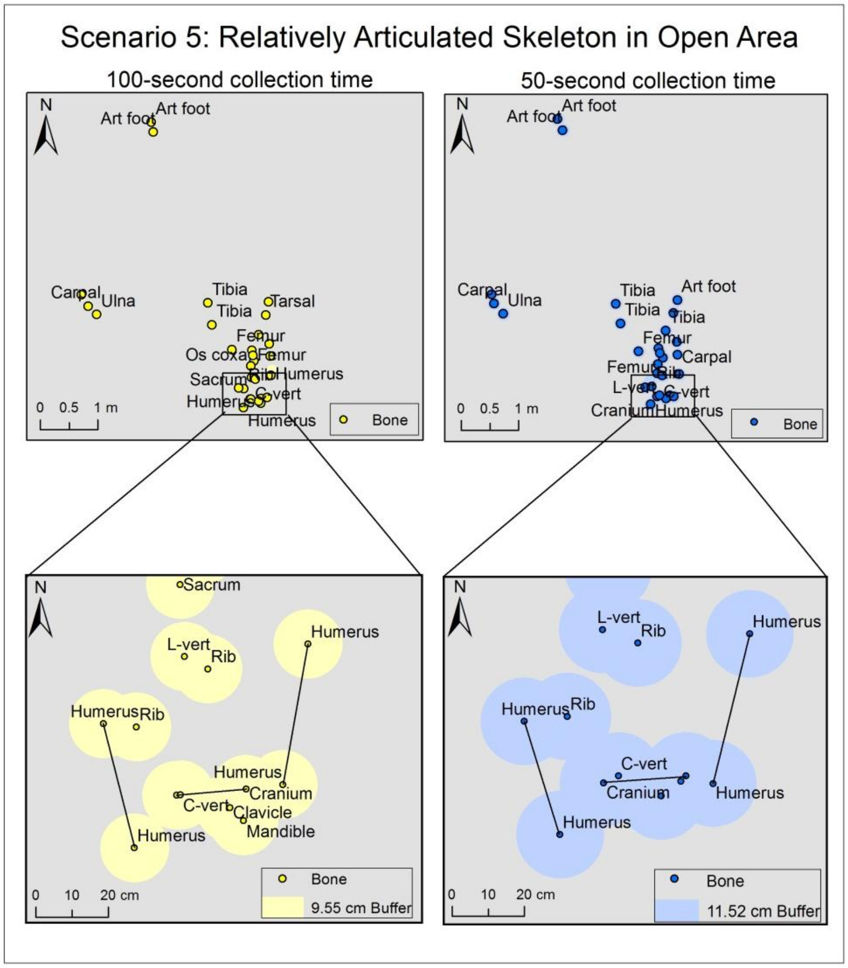

Figure 35- Map of 100-second and 50-second collection times with accuracy buffers for Scenario 5 using ArcMap

Scenario 6

Scenario 6 consisted of a relatively articulated skeleton in a tree-covered area using 50-second and 100-second collection times. Productivity settings were increased for features in locations that were too obstructed for standard data collection. Offsets were implemented for skeletal elements when locational data could not be obtained using the highest productivity setting. This scenario was differentially corrected against the DLND basestation during postprocessing. Interestingly, increased collection time for point data collected in Scenario 6 maintained the orientation and maximum length of most long bones (Figure 36), unlike the previous scenarios in tree-covered areas (Scenarios 2 and 4). This may have been due to exceptional satellite geometry obtained during data collection. However, the close proximity of the features and increased buffer radius resulted in excessive overlap of the collected features.

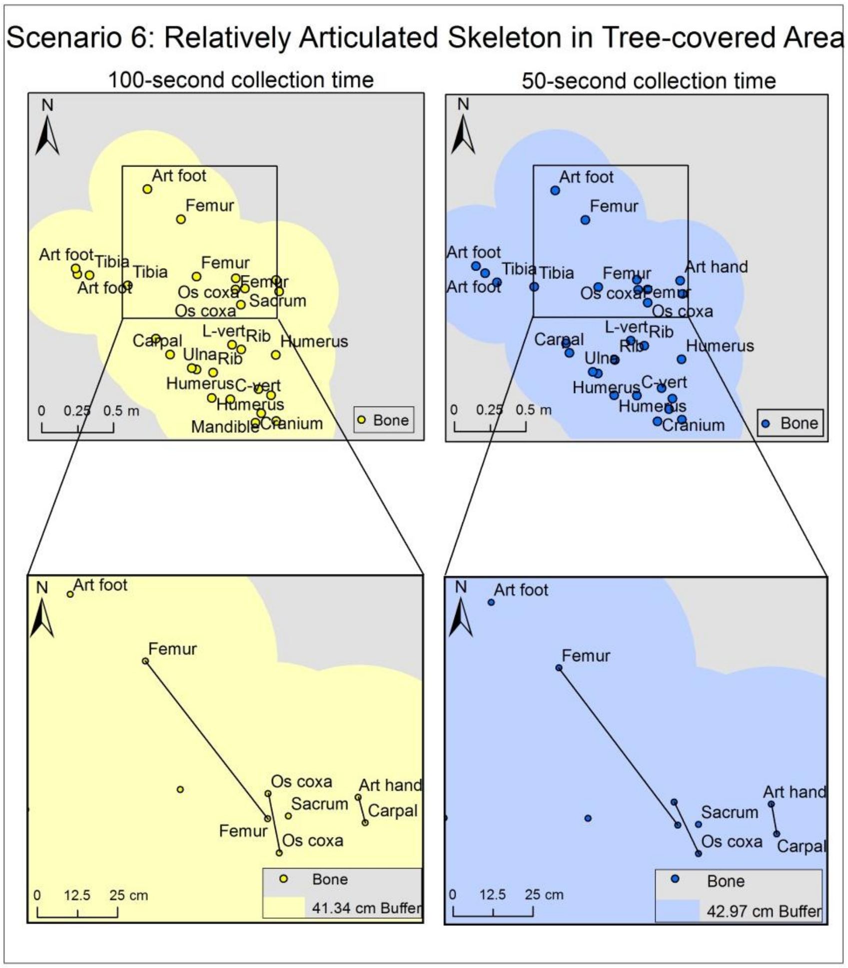

Figure 36- Map of 100-second and 50-second collection times with accuracy buffers for cenario 6 using ArcMap

Scenario 7

Scenario 7 consisted of a wide skeletal dispersal in an area near a tall structure using 50-second and 100-second collection times. Productivity settings were increased for features in locations that were too obstructed for standard data collection. Offsets were implemented for skeletal elements when locational data could not be obtained using the highest productivity setting. This scenario was differentially corrected against the DLND basestation during postprocessing.

Increased collection time in Scenario 7 slightly changed the orientation for most of the long bones, but maintained the general direction of the element (Figure 37). Additionally, the maximum lengths of the long bones were maintained for both collection times in this environment. However, considerable overlap of error buffers for this type of dispersal was noted.

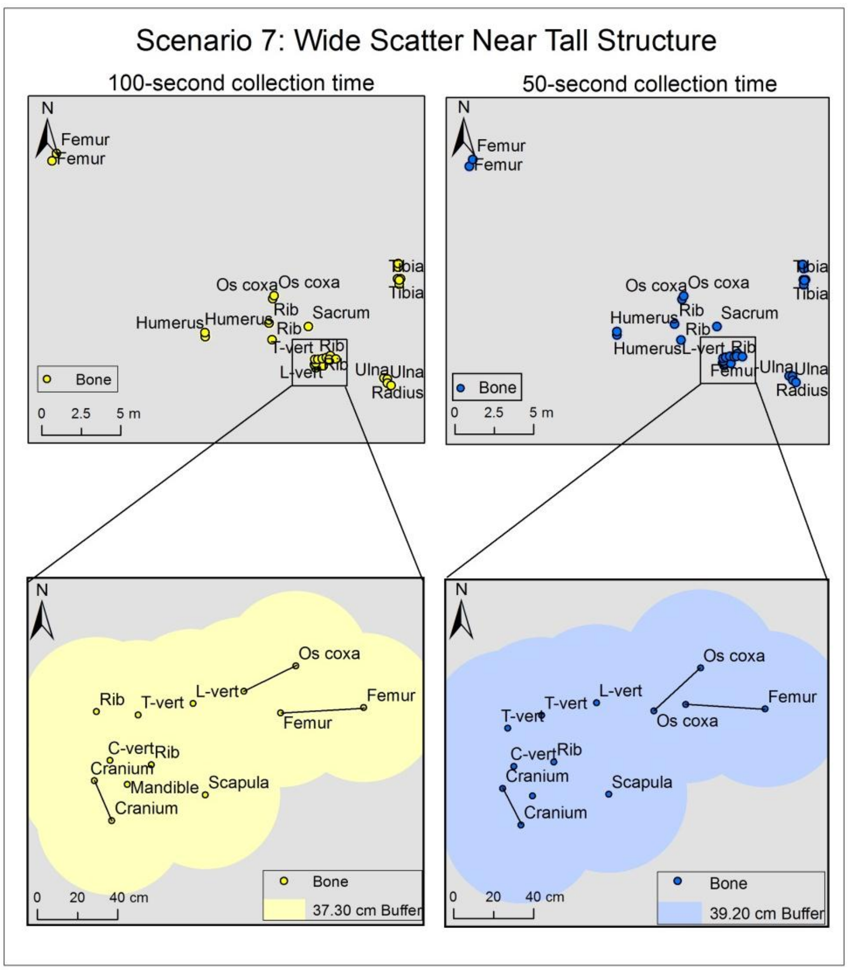

Figure 37- Map of 100-second and 50-second collection times with accuracy buffers for Scenario 7 using ArcMap

Scenario 8

Scenario 8 consisted of a tight skeletal dispersal in an area near a tall structure using 50-second and 100-second collection times. Productivity settings were increased for features in locations that were too obstructed for standard data collection. Offsets were implemented for skeletal elements when locational data could not be obtained using the highest productivity setting. This scenario was differentially corrected against the DLND basestation during postprocessing.

Increased collection time for point data collected in Scenario 8 demonstrated a noteworthy difference in the maximum lengths for all long bones collected in this scenario (Figure 38). The general orientation of the long bones, however, was maintained. This contrasts to the point data collected in Scenario 7 (wide scatter near a tall structure), where the maximum length of the long bones was maintained and the orientation of the long bones was slightly effected.

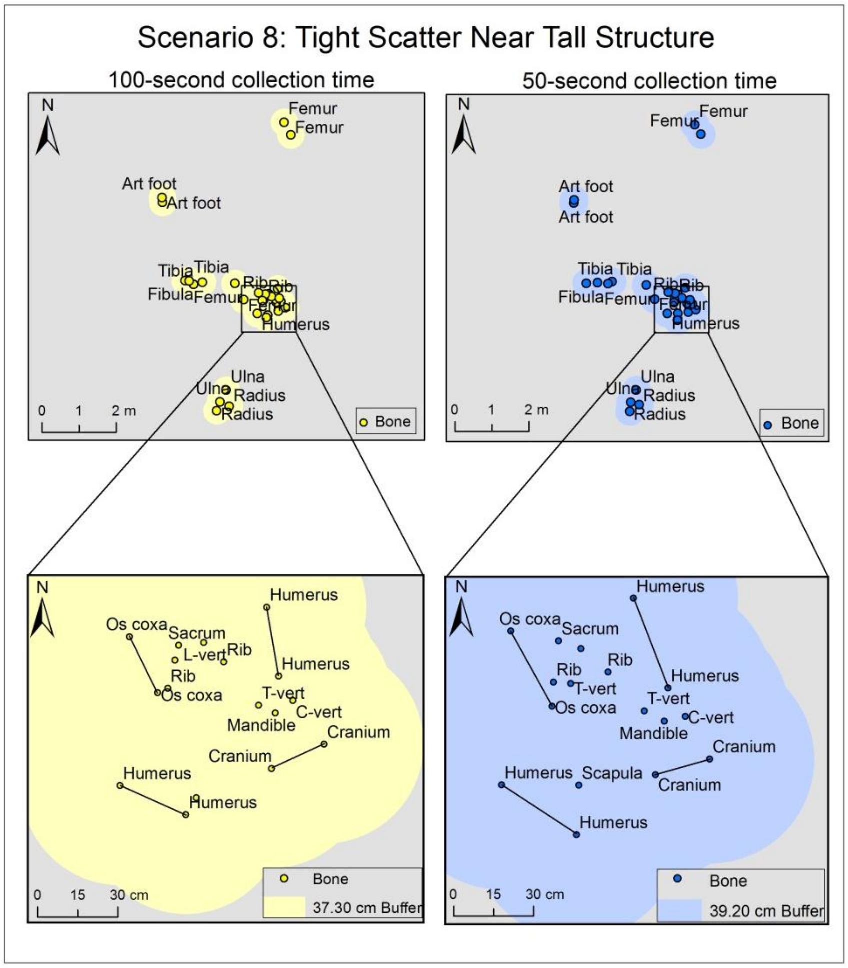

Figure 38- Map of 100-second and 50-second collection times with accuracy buffers for Scenario 8 using ArcMap

Scenario 9

Scenario 9 consisted of a relatively articulated skeleton in an area near a tall structure using 50-second and 100-second collection times. Productivity settings were increased for features in locations that were too obstructed for standard data collection. Offsets were implemented for skeletal elements when locational data could not be obtained using the highest productivity setting. This scenario was differentially corrected against the DLND basestation during postprocessing.

Like Scenario 8, the orientation of the long bones was not considerably affected with increased collection time; however, the maximum lengths of the long bones were influenced by the obstructed environment (Figure 39). A difference of maximum length for a majority of long bones was demonstrated. Additionally, considerable overlap of the collected features for this type of dispersal was noted.

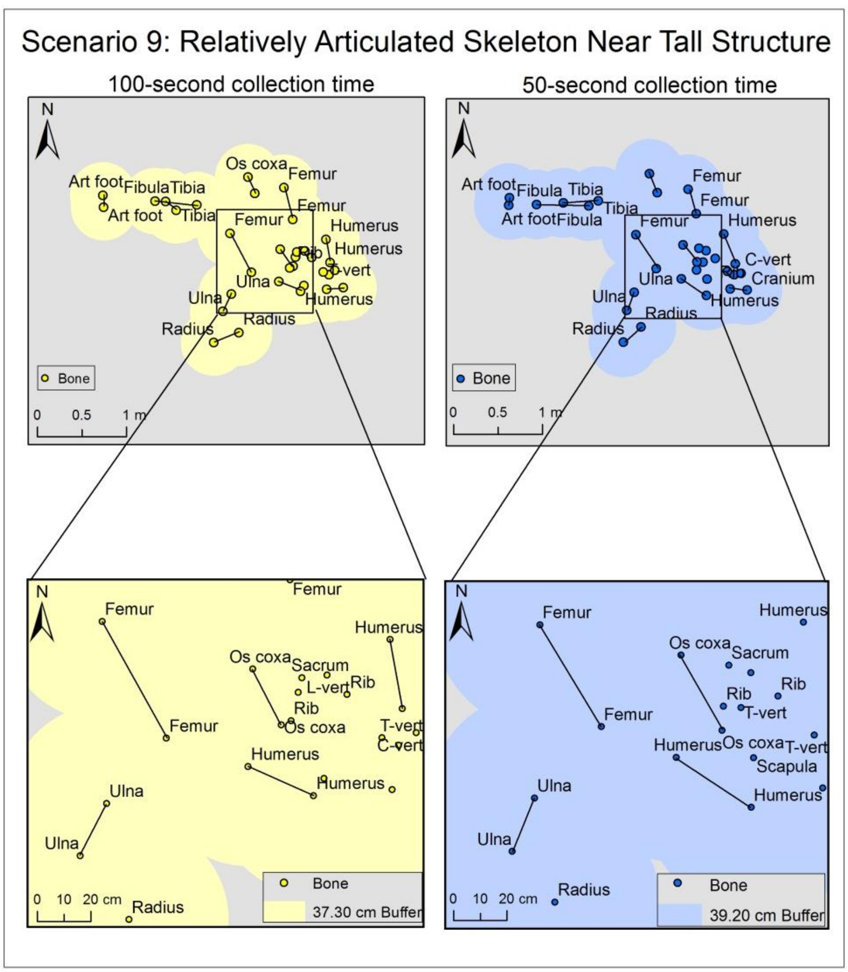

Figure 39- Map of 100-second and 50-second collection times with accuracy buffers for cenario 9 using ArcMap

Discussion

The point data collected for the scenarios in open areas (Scenarios 1, 3 and, 5) demonstrated a consistent maintenance of long bone orientation and maximum length (Table 13). Furthermore, the overlapping of features in open areas was limited because of the decreased radius of the error buffers. This lack of overlap was demonstrated in all types of dispersals for open environments.

Scenarios in obstructed environments, however, did not produce favorable results when compared to point data collected in scenarios with open areas (Table 13). Preservation of orientation and maximum length of long bones varied between dispersal and environment. The point data collected in the area near a tall structure consistently maintained the general orientation of the long bones but did not maintain the maximum length of the long bones. Additionally, the increased radius of the error buffers for both obstructed environments resulted in considerable overlap of clustered features.

Table 13- Summary of results for maximum long bone length, long bone orientation, and buffer overlap of Scenarios 1-9

Scenario #	Scenario type	Maximum long bone length	Long bone orientation	Buffer overlap
1	Open wide scatter	Maintained	Maintained	Minimal overlap
2	Tree-covered wide scatter	Not maintained	Not maintained	Overlap
3	Open tight scatter	Maintained	Maintained	Minimal overlap
4	Tree-covered tight scatter	Not maintained	Not maintained	Overlap
5	Open relatively articulated skeleton	Maintained	Maintained	Minimal overlap
6	Tree-covered relatively articulated skeleton	Maintained	Maintained	Excessive overlap
7	Wide scatter near a structure	Generally maintained	Maintained	Overlap
8	Tight scatter near a structure	Generally maintained	Not maintained	Overlap
9	Relatively articulated skeleton near a structure	Not maintained	Generally maintained	Excessive Overlap

Furthermore, the implementation of decreased productivity settings was necessary in order to gain good satellite geometry for data collection. This resulted in a severely increased data collection time in the field, as it is necessary to increase the productivity and wait for satellite location to be gained. If good satellite geometry is not obtained with the first level increase of productivity, the productivity must be increased again and the user must wait for the satellite location to be gained. This step is repeated until good satellite geometry can be obtained for sufficient locational data to be collected. If the feature was heavily obstructed and good satellite geometry could not be obtained, the use of an offset was implemented. Offsets greatly increased data collection time, as two measurements, the bearing angle and distance measurement, must be collected in addition to moving the DGPS unit to an open area where location information can be collected. However, if several elements are located in a heavily obstructed area, the DGPS may remain stationary while the bearing angle and distance measurement is collected for each feature.

Conclusions

Mapping dispersed remains and associated evidence in the field can be challenging because of long distances and varied environments in which human remains are found. The purpose of this research was to determine if a DGPS unit was a reliable option for mapping skeletal dispersals. It is concluded that mid-price DGPS units are a viable option for mapping skeletal dispersals in open environments. Scenarios mapped in open environments produced consistent results for all types of skeletal dispersals and maintained the orientation and maximum length of long bones. Also, the decreased error determined from the previous chapter did not result in significant overlap of clustered elements.

Conversely, this research also demonstrated that DGPS units do not provide the accuracy and consistency necessary to properly map skeletal dispersals in obstructed environments. The orientation and maximum lengths of the skeletal elements were constantly inaccurate in these environments, demonstrating that error introduced from obstructions severely affected collection of location data. Also, the error determined in the previous chapter resulted in constant overlap of proximate skeletal elements. Thus, the collection of locational information for datums at obstructed sites may be utilized to tie in positional information of the entire site but should not be used to separately map skeletal elements.

This is the first research developing a methodology for determining the accuracy of a DGPS unit in different environments using survey markers and applying the calculated accuracy to simulated scenarios in different environments. Further research, however, is necessary to ascertain the applicability of DGPS units in mapping skeletal dispersals. Most importantly, it is necessary for additional DGPS units to be tested and compared to the Trimble GeoExplorer 2008 Series receiver. Also, the accuracy of DGPS units in additional obstructed environments (*i.e.* areas near mountains) and mixed environments should be determined. Further, real-time differential postprocessing should also be considered in future research.

CHAPTER FOUR: INTEGRATING DGPS DATA INTO A GIS

Introduction

GIS systems are equipped with an abundance of tools that are valuable in analyzing and mapping DGPS data. However, the literature is limited concerning how DGPS data used for mapping skeletal dispersals can be analyzed in a GIS. Listi et al. (2007) mentions the benefits of using a GIS for analyzing and mapping skeletal dispersals but does not explain how data may be integrated into a GIS or what tools may be beneficial in analysis and mapping human remains. Manhein et al. (2006) utilized a GIS on a larger-scale and conducted spatial analysis of several dumpsites; however, this study used a single coordinate for an entire site and did not consider spatial analysis of the elements within a site. It was not until Spradley et al.'s study (2011) concerning spatial patterning of vulture scavenging, that DGPS data from a single skeletal dispersal was analyzed and mapped in a GIS.

This chapter will discuss the benefits of integrating DGPS data into a GIS for analysis and generating maps. Additionally, this chapter will summarize the findings of the research conducted and discuss the desirable conditions in which a DGPS unit may be utilized in mapping skeletal dispersals. Most importantly, guidelines and best-of-use practices when employing a DGPS unit in mapping skeletal dispersals will be provided.

Geographical Information Systems

In order to understand how the integration of DGPS data into a GIS can be useful in mapping human remains, it is important to first understand the mechanics of GIS. A GIS is best described as a set of tools used for analyzing spatial data (Napton and Greathouse, 2009). It is software that has the capability to display spatially referenced data, analyze data in a spatial geodatabase, and generate maps. Most importantly, a GIS allows spatial information to be converted into useful data, stored, analyzed, and then displayed (Clarke, 1995; Napton and Greathouse, 2009).

GIS software stores attribute data in a database and then references this data to geographical data that has been collected or is readily available in the software (ESRI, 1990). GIS software may then be used to manipulate and analyze the data, in addition to generating maps for presentation. GIS was developed primarily from computer mapping systems and remote sensing technology in the 1990's. It has since been utilized to represent and model geographic and archaeological data (Napton and Greathouse, 2009).

Analysis of DGPS data in GIS

Primarily, the use of a GIS in archaeology has been to demonstrate the relation of past social systems in relation to their environment in addition to quantitative site location analysis (Conolly and Lake, 2006). As mentioned earlier, research concerning the use of a GIS in smaller scenes, such as skeletal dispersals, however, has only been considered by a single study. Spradley et al. (2011) utilized DGPS data in a GIS to analyze the spatial distribution of skeletal elements from vulture scavenging in a controlled study, but did not develop a methodology concerning the utility of the DGPS unit in mapping. Though several tools were used to analyze DGPS data in GIS, the study focused on dispersal patterns, rather than the data collection and accuracy of the DGPS.

However, the preliminary research conducted by Spradley et al. (2011) for spatial analysis of a dispersal using GIS demonstrates that GIS analysis can serve as a beneficial tool in analyzing a scene. This study shows that descriptive spatial analytical and spatial statistics measures can be utilized to summarize special patterns in the displacement of remains. Furthermore, the calculation of a Mean Center, a point that identifies the geographic center of a set of locations, of the remains can be determined using GIS software to track changes in the distribution of a certain feature. Additionally, the extension and direction of scattered remains can be analyzed using Directional Distribution, which measures the directional trend of a set of features, and Standard Distance, which measures the degree of dispersion of features around the determined Mean Center.

Though Spradley et al. (2011) utilized sophisticated spatial analyses in their study, simpler tools available in a GIS can be used as well. For example, the measuring tool measures the distance between points for analysis (Figure 40). Area may also be measured by drawing a polygon with the cursor and entire features may be measured by selecting the feature, which is particularly useful in a courtroom setting if the witness is asked for a measurement between features to show context of a scene.

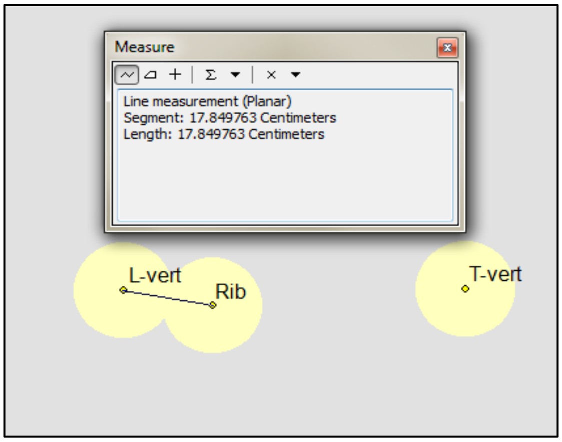

Figure 40- Screenshot of measuring tool in ArcMap from Scenario 1

The buffer tool is convenient when the user is looking to illustrate the possible error of the DGPS unit, demonstrated in Chapter 3. This tool creates buffer polygons around input features to a specified distance. Also, an optional dissolve can be performed to combine overlapping features. In addition to illustrating error of a unit, this tool can be used to show the diameter for a group of clustered skeletal elements.

As mentioned previously in this chapter, preliminary research has been conducted concerning spatial analysis at both small-scale and large-scale levels. There exists an abundance of spatial analysis tools available in GIS that have yet to be explored. For example, Cluster and Outlier Analysis or Hot Spot Analysis (Figure 41), identifies statistically significant hot spots, cold spots, and spatial outliers and has the potential to be beneficial in dispersals with more than a single individual to aid in the determination of primary deposition location. Additionally, the use of Spatial Autocorrelation (Figure 41), which measures autocorrelation based on feature locations and attribute values, could be beneficial in assessing the dispersal patterns of bone type at a scene to better understand the distribution of the elements since deposition.

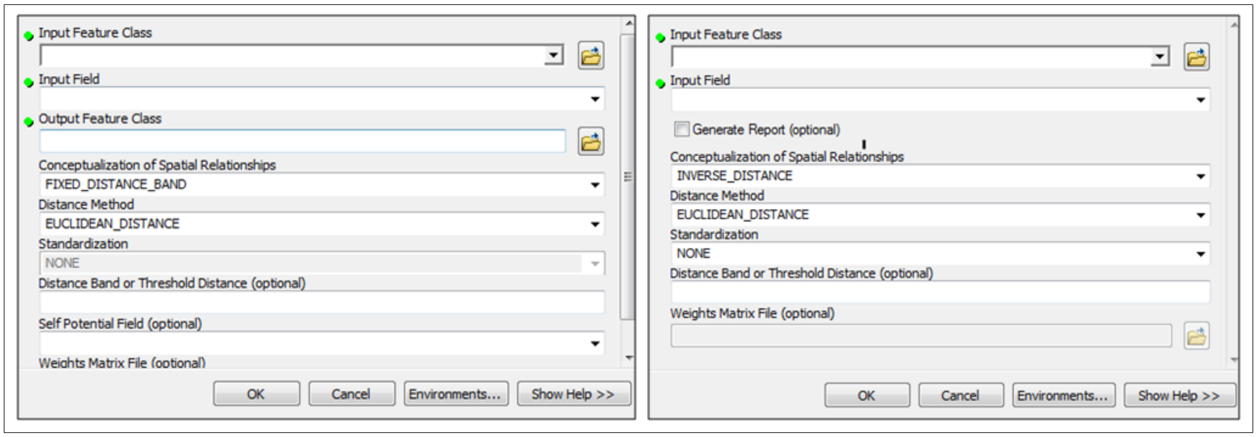

Figure 41- Screenshots of data input for Hot Spot Analysis and Spatial Autocorrelation tools in ArcGIS

Creating Maps Using DGPS data in GIS

In addition to analysis in a GIS, an advantage of integrating DGPS data in a GIS is to create detailed maps of a scene. GIS has several features that may be utilized to clearly illustrate the scene as it was in the field and highlight aspects of the scene that were not recognized in the field. One example is the one-click addition of a basemap available in ESRI ArcMap version 10, which allows the user to add an aerial image to the DGPS data. The addition of a basemap brings context to the scene by adding streets, trees, and other landmarks. Basemaps add a broader perspective of the scene for wide scatters, showing possible dispersal patterns in accordance with surrounding features, such as changes in vegetation or streets. Aerial images also are appealing in a courtroom setting when it is necessary for jurors to understand the overall location of a scene.

Several types of basemaps can be added to georeferenced data in ArcMaps version 10 such as aerial imagery, road and street maps, topographic maps, and terrain maps (Figure 42). However, the resolution of the aerial imagery is limited and is not appropriate for all dispersal scenarios. When considering the data collected for this research, one can retain contextual information in an aerial photo with wide scatters of at least 30 meters when compared to tight scatters (Figure 43). Furthermore, aerial basemaps can be useful in all outdoor environments such as tree-covered and urban areas (Figure 44). The spatial relationship of skeletal elements to manmade features, such as buildings or sidewalks, and natural features, such as trees, can be easily illustrated. Additionally, basemaps with roads can be used for dispersals in urban areas to add contextual information (Figure 45). Most importantly, basemaps are beneficial in illustrating the location of an entire scene for any level of skeletal dispersal with any type of environment using a variety of basemaps.

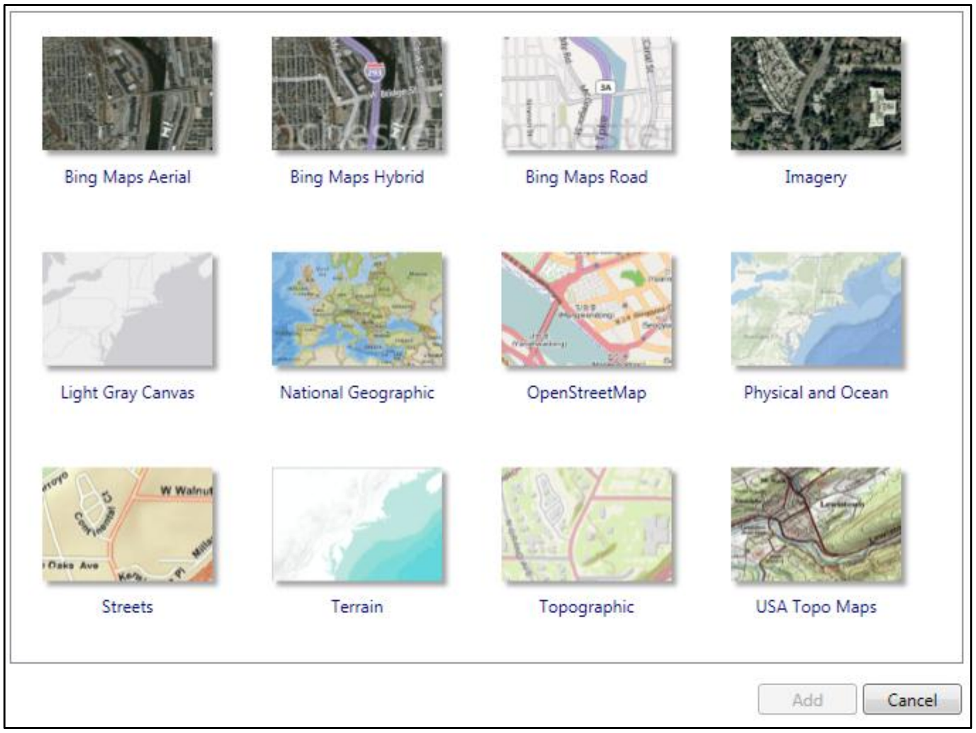

Figure 42- Screenshot of basemap feature in ArcMap

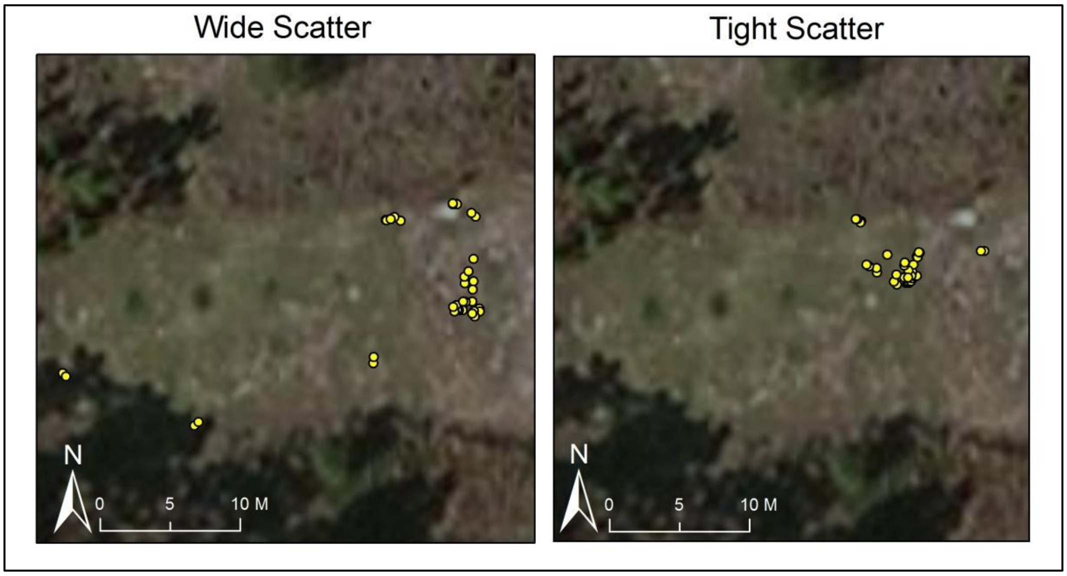

Figure 43- Composite image from ArcMap of aerial basemaps of a simulated wide scatter (left) and a simulated tight scatter (right).

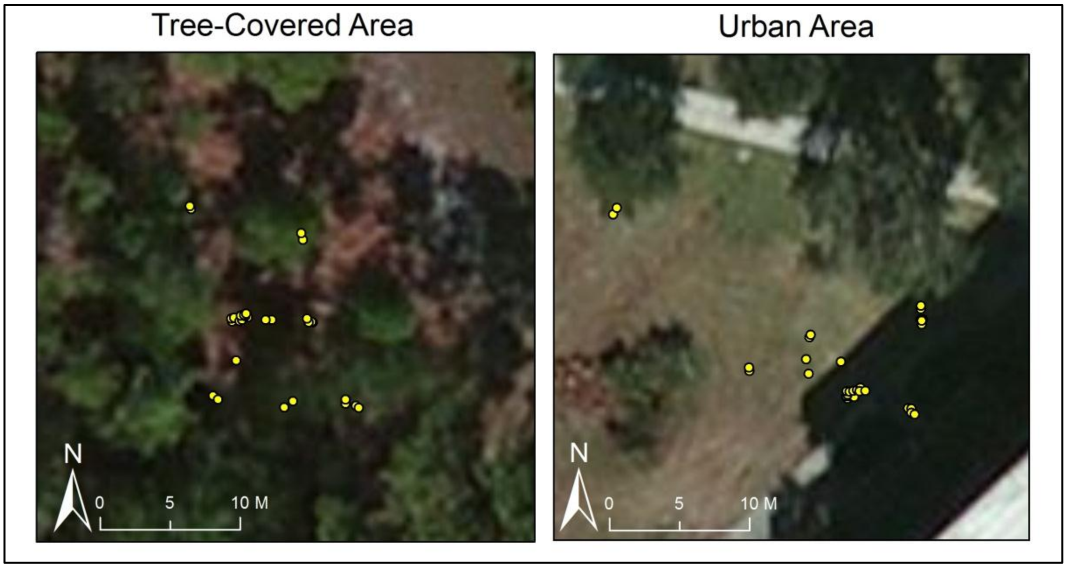

Figure 44- Composite image from ArcMap of aerial basemaps of simulated skeletal dispersals in a tree-covered area (left) and an urban area (right)

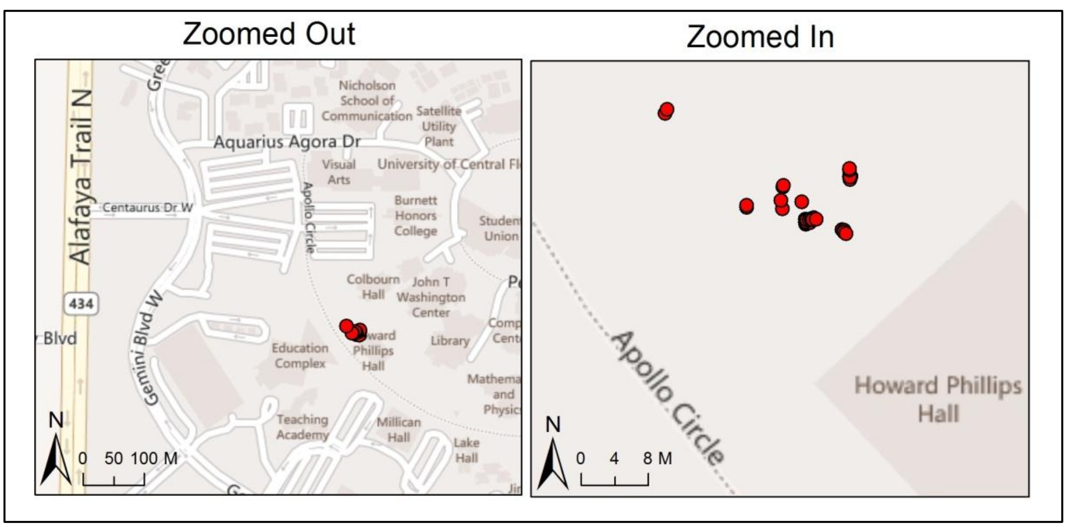

Figure 45- Composite image from ArcMap of a roads basemap of a skeletal dispersal in an urban area, both zoomed out (left) and zoomed in (right)

In addition to adding a basemap layer to DGPS data, elements can be easily labeled or highlighted by using drawing tools. Users can label elements in a variety of ways using various colors to highlight certain features. Data may be grouped according to attribute data collected in the field such has bone type, completeness, or side. Legends can then be generated by GIS for maps. Shapes can also be added to emphasize features, group features together, or connect features via lines. Text can be added by labeling points with attribute data or can be added to a map manually. Additionally, the callout tool can be used to add information to a location or label a feature (Figure 46). The bookmark tool can save the parameters for an area of interest. This is useful for presentation purposes when the user wishes to zoom in or out of a known area on queue without making multiple maps (Figure 47).

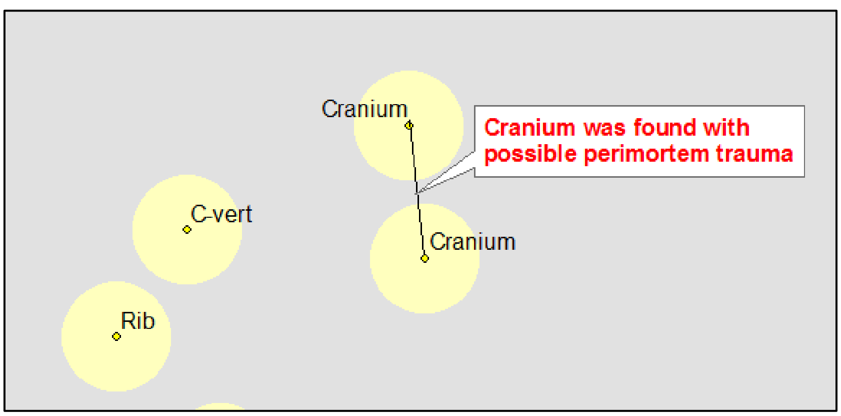

Figure 46- Screenshot of callout tool in ArcMap from Scenario 1

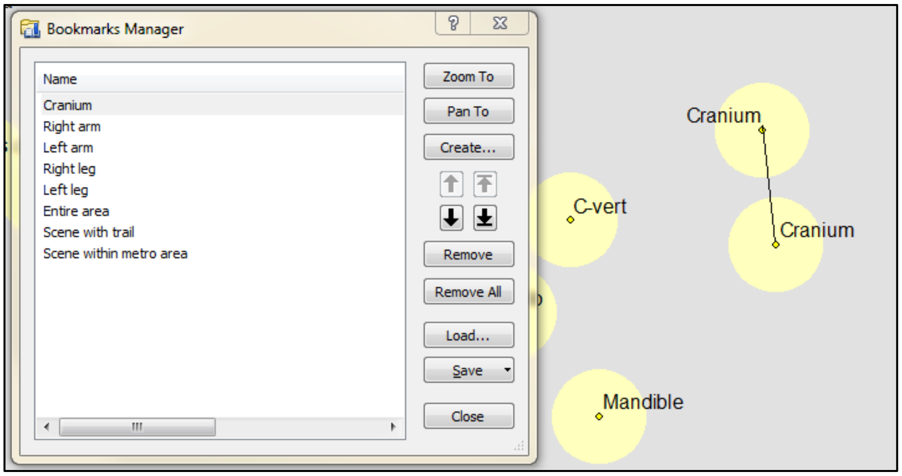

Figure 47- Screenshot of bookmark tool in ArcMap from Scenario 1

Attribute information collected in the field can serve as a preliminary skeletal inventory or valuable cross-reference for a skeletal inventory. Furthermore, attribute data of separate features can be grouped according to bone type, allowing the user to visually catalog the remains that were collected in the field. Also, the time at which positional data is collected in the field is automatically recorded and exported as attribute information for each feature which can aid in maintaining the chain of custody during. This may also be implemented for associated evidence at the scene.

Finally, one of the most beneficial reasons for using a GIS to generate maps of scene is that throughout the map-making process, geospatial information is retained. Georeferenced data will not change from zooming in and out or by adding additional layers for comparison purposes. All of the features, shapes, and layers added to the map will stay to scale and all geospatial will be maintained.

Guidelines for Data Collection of DGPS data

Before data collection can occur, it must be determined if mapping using a DGPS unit is appropriate for the scene in question. This research determined that a mid-price DGPS unit is not a viable tool in mapping skeletal dispersals in obstructed environments. However, a DGPS unit may be utilized to map skeletal dispersals in open environments when certain practices are implemented for data collection and postprocessing. The use of traditional mapping methods such as a compass survey or baseline may introduce additional error from long distances and obstructions for widely dispersed remains (Listi et al., 2007). Furthermore, a total station may not be a viable mapping method in these situations because of the obstruction of the line of site over long distances which results in the relocation of the transit point to gain an accurate sight line from the total station unit to the stadia point (Listi et al., 2007; Napton and Greathouse, 2009; Dupras et al., 2011). It is in scenarios such as these that a DGPS unit may be a better option because of its portability and ease of use in wide skeletal dispersals, in addition to the geospatial information that can be provided from using a DGPS. However, for situations with a relatively articulated skeleton or skeletal elements in close proximity, a DGPS unit may not be the best mapping option. Moreover, if the remains are located in an obstructed environment, an error range of approximately 40 cm is not appropriate when a more accurate method, such as a baseline, may be employed.

Before a DGPS unit is used for mapping purposes, the accuracy of the unit must be determined by comparing coordinate information to a known survey marker. This may be accomplished by following the practices provided in the Materials and Methods section of Chapter 2. Data concerning survey markers may be obtained from the Department of

Transportation in the user's area. If the error determined by the DGPS unit is within the accuracy range desired by the user, the DGPS unit may be employed in similar environmental scenarios (*i.e.* open area error applied to dispersals in open areas).

Furthermore, developing a consistent methodology for data collection is crucial for mapping any scene. By following predetermined procedures, there is less of a chance of introducing additional error or not including important information. Before data collection, determine how the point data will be collected for each skeletal element. For example, all long bones may be measured using proximal and distal ends, while short bones, such as vertebrae, will be measured at predetermined aspects, such as the anterior of the body. Furthermore, a rangepole should be used to better pinpoint the exact location of the element that the user is measuring. The addition of a tripod to the rangepole is recommended to keep the DGPS unit straight and level during location acquisition. Per Chapter 2, it is recommended that bones longer than 25 cm would be mapped using two points to illustrate orientation, while bones less than 25 cm should be mapped using a single point. Additionally, it is recommended that clustered elements less than 25 cm apart should be measured as a single element, while clustered elements grouped farther than 25 cm apart should be measured as separate features. Furthermore, when collecting point data for more than one feature, information concerning the type or description of skeletal element should be recorded during data collection. For a full list of points used to collect points of skeletal elements in this research, see Table 11.

After determining how point data will be collected for each type of bone, a data dictionary should be created to include any additional attribute information. It is recommended that the following information be included in order to ensure a complete inventory of the skeletal elements and characteristics:

- Bone type (*i.e.* cranium, mandible, etc.)
- Side
- Completeness (*i.e.* complete, 75%, etc.)
- Aspect (*i.e.* proximal, distal, etc.)
- Collection time
- Environment type
- Date collected
- Time collected
- Notes

It is possible to assign default selections to a field within the data dictionary, such as type of environment, to save time during data collection. Also, time of data collection and date of data collection can be generated by the software instead of being entered manually. Another advantage of using a data dictionary is that the software will not allow the user to save a feature unless all of the required information is entered, ensuring that crucial information is not missed in the field. Additionally, by including a field for notes in the data dictionary, the user is free to include any additional information concerning the feature. Finally, it is recommended that the data dictionary be as generic as possible, so that it may be applied to several types of scenes without having to create a new data dictionary each time a scene is mapped.

An important part of successful data collection is good satellite geometry, which is the desired number and position of satellites for optimal accuracy during data collection (Bolstad, 2005). To achieve good satellite geometry, it is recommended that the user consult a satellite almanac to determine the best time of day for data collection. Thus, prior to the day of data collection, the best time for data collection can be determined by consulting preplanning software. Planning almanac software is free, available through Trimble or other major DGPS retailers, and is obtainable up to a year in advance. This software provides information including the satellite position data, DOP data, and elevation data on specific days. It is recommended that data collection be determined by considering the greatest number of satellites, with at least 4 satellites being the most desirable, and the least PDOP value, with values less than 2 being the most desirable (Johnson and Barton, 2004). Time windows fitting these characteristics should be at least 3 hours long to allow for any unforeseen circumstances. If preplanning is not possible, it is recommended that the PDOP value and number of satellites be recorded if poor satellite geometry were to occur, as this may explain an increased error of point data.

After a data collection method has been established and once the best time of day for data collection has been determined, point data may be collected in the field. It is recommended that all predetermined methods be executed consistently throughout the data collection process. First, skeletal elements and evidence should be flagged, so that features are not missed. It is also recommended that the DGPS unit be oriented vertically, so as not to degrade satellite reception (Sando et al., 2005). If possible, one user should conduct the entire survey, so that possible error from differences in data collection methods is not introduced and features are not skipped.

The collection time for point data should be determined in consideration of the number of elements to be mapped and the amount of time available in the field. The collection time should be as long as possible, as increased collection time adds point data that will be averaged for the final coordinate. It is recommended that at least a 100-second collection time be implemented, as this collection time was found to be more accurate than a 50-second collection time; however, if time is a factor a 50-second collection time was found to provide sufficient accuracy in open areas. Once the collection time is determined, this collection time should be utilized for all point data.

After positional data has been collected for the objects of interest, collected features should be cross-checked with the flagged skeletal elements and evidence. This may be accomplished by looking at the list of features collected or with a map of the area on the data view screen. The user may also collect features such as trail entrances, datums, and buildings to give context to the site. This may be accomplished by creating lines for roads or polygons for buildings using the DGPS unit or simply with point data.

Once all data has been collected, it is necessary to transfer the data to a computer where the data will be differentially corrected against a nearby basestation. After the data is transferred, the data must be imported into differential correction software such as Pathfinder Office. Generally, there is a short amount of lag time (approximately 1 to 2 hours) in receiving basestation data. When choosing a basestation to differentially correct the DGPS data against, it is crucial to choose the basestation that is within the closest proximity to the scene at which the data was collected. Trimble recommends postprocessing against a basestation with an integrity index of 80 or higher and that is within 200 kilometers of the site (Trimble Navigation Limited, 2009). Once the data has been successfully corrected, data must then be exported as a shapefile for analysis in a GIS. Figure 49 shows a flowchart of the guidelines provided in this chapter.

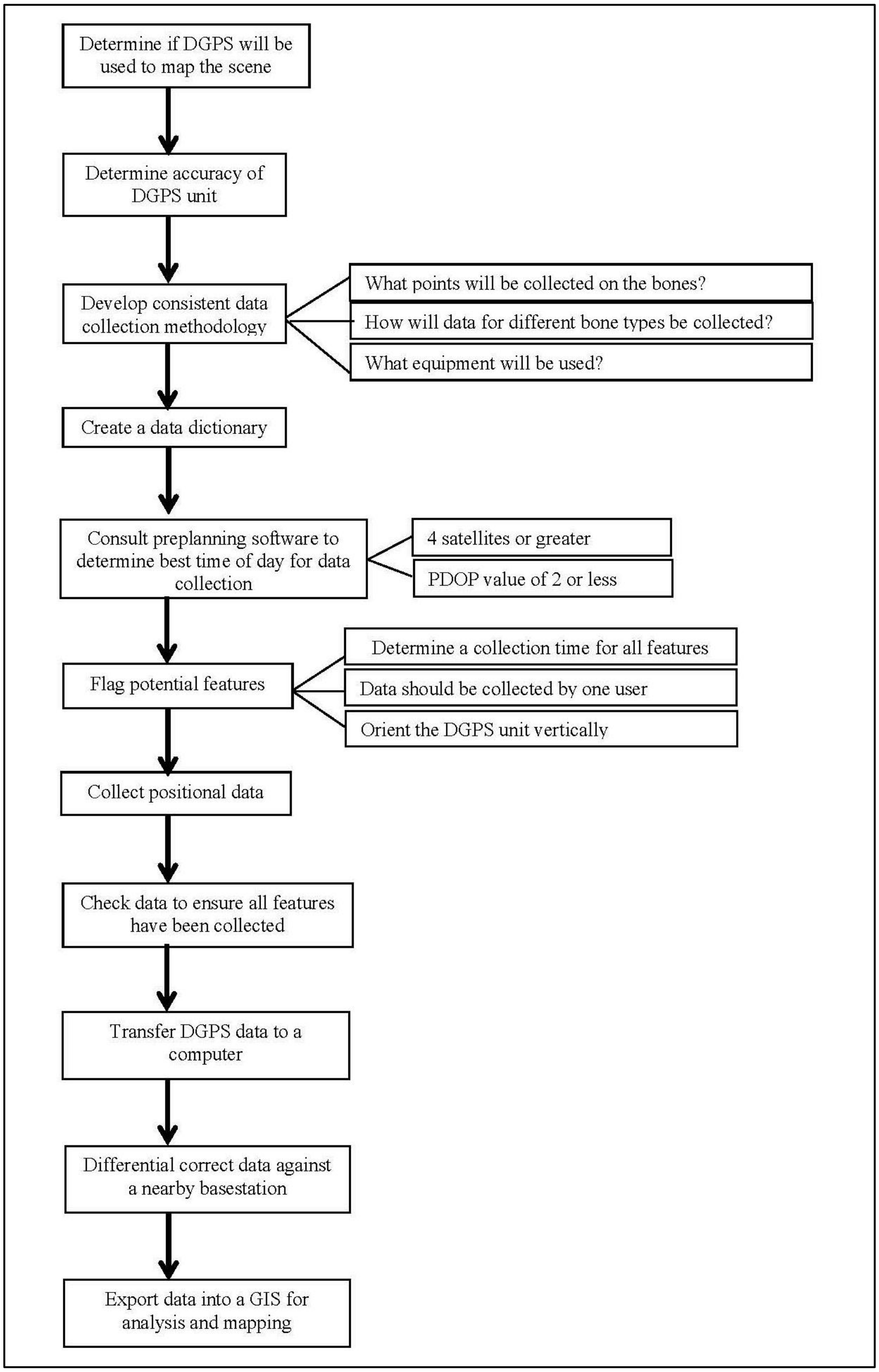

Figure 48- Flow chart of guidelines for collecting and processing DGPS data for skeletal dispersals

Conclusion

This chapter explored the various options that are available by integrating DGPS data from a scene into a GIS. Several tools may be employed to investigate the spatial distribution of remains and analyze scatter patterns of a skeletal dispersal; however, an abundance of tools available in GIS analysis have not yet been used to assess their usefulness for a scene with human remains. Thus, further research with these tools is necessary to determine their applicability and practicality for analyzing skeletal dispersals.

In addition to spatial analysis of DGPS data in a GIS, this chapter considered the advantages of using a GIS for generating maps of a skeletal dispersal. Several tools such as the addition of a basemap, shapes, text, and colors can be utilized to illustrate the scene as it was in the field. Furthermore, these tools may be used to highlight certain aspects of a scatter while preserving geospatial information for the features collected at the site.

Finally, detailed guidelines concerning the use of a DGPS unit in mapping skeletal dispersals were provided. Because of decreased accuracy from obstructions, scenes in open environments should only be used for mapping. It was found in Chapter 3 that scenes with obstructions such as trees or tall buildings significantly affected the accuracy of the DGPS unit. With the consideration to the environment in which DGPS data will be collected, the use of guidelines provided in this chapter can provide an accurate depiction of dispersed human remains and associated evidence, while maintaining geospatial information and attribute data of the features collected.

This research has served as the first thorough investigation utilizing a DGPS unit and GIS in mapping scattered human remains. As mentioned previously, research concerning the use of

DGPS equipment and GIS software in scene mapping and analysis is limited. Additional research must be conducted to assess the practicality and applicability of these utilities for mapping skeletal dispersals. Further research using additional DGPS units in other environments is needed to assess the practicality of this utility in additional scenarios. Furthermore, additional research concerning the integration of DGPS data into a GIS must be conducted to explore additional tools that may be valuable in the analysis of scenes with scattered remains for both small-scale and large-scale situations.

APPENDIX A: SURVEY MARKERS

FDOT D5 PID	90501004

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:34:58 P

DATA PROVIDED IS FOR INFORMATIONAL PURPOSES ONLY. DATA IS SUBJECT TO CHANGE AND REVISION WITHOUT NOTICE TO THE USER. USER ASSUMES ALL RISK AND LIABILITY FROM DATA USAGE UNLESS AUTHORIZED OTHERWISE BY FDOT.

DUE TO THE USE OF AUTOMATED IMPORTATION PROCESSES INTO THE PNC DATABASE THE PUBLISHED VALUES AS DEPICTED IN THIS REPORT MAY BE EXPRESSED AT A HIGHER PRECISION THAN ACTUALLY DETERMINED. PLEASE REFER TO THE POSITIONAL QUALITY STATEMENT FOR EACH PUBLISHED COMPONENT TO DETERMINE APPROPRIATE USAGE PRECISIONS.

HECTOR_NAME	90501004
GOT_VECTOR	☑
EFB_NAME	N/A
3WIRE_NAME	N/A
GOT_LEVEL	☐
DESTROYED STATION	☐
ELE STATION	☐
REVIEWED	☑
LOST STATION	☐
NOT CONNECTED	☐
PRECISE LATITUDE / LONGITUDE — LATITUDE	29 01 40.67301
PRECISE LATITUDE / LONGITUDE — LONGITUDE	81 18 26.67263
APPROXIMATE LATITUDE / LONGITUDE — LATITUDE	N/A N/A N/A
APPROXIMATE LATITUDE / LONGITUDE — LONGITUDE	N/A N/A N/A
LATITUDE / LONGITUDE POSITIONAL QUALITY	PPHNC BY GPS NETWORK OBSERVATIONS
LATITUDE / LONGITUDE REFERENCE DATUM	NAD 83 (1990)
LATITUDE / LONGITUDE PUBLICATION SOURCE	PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.
ELLIPSOID HEIGHT IN US SVY FEET	-53.4874
ELLIPSOID HEIGHT IN METERS	-16.3030
ELLIPSOID HEIGHT REFERENCE DATUM	NAD 83
ELLIPSOID HEIGHT POSITIONAL QUALITY	PPHNC BY GPS NETWORK OBSERVATIONS
ELLIPSOID HEIGHT PUBLICATION SOURCE	PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.
SPC - NORTHING US SVY FEET	1706585.6213
SPC - NORTHING METERS	520168.3377
STATE PLANE PROJECTION SCALE FACTOR	.99995224
SPC - EASTING US SVY FEET	557925.8759
SPC - EASTING METERS	170056.1471
STATE PLANE ZONE	FLORIDA EAST
STATE PLANE COORDINATE POSITIONAL QUALITY	PPHNC BY GPS NETWORK OBSERVATIONS
STATE PLANE PUBLICATION SOURCE	PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.
DIFFERENTIALLY LEVELED ORTHOMETRIC HEIGHT — DL ORTHOMETRIC HEIGHT IN US SVY FEET	N/A
DL ORTHOMETRIC HEIGHT IN METERS	N/A
ORTHOMETRIC HEIGHT DATUM	NAVD 88
GPS DERIVED ORTHOMETRIC HEIGHT — GPS ORTHO HEIGHT IN US SVY FEET	38.1298
GPS ORTHO HEIGHT IN METERS	11.6220
ORTHOMETRIC HEIGHT POSITIONAL QUALITY	APPROXIMATE BY GPS NETWORK OBSERVATIONS
ORTHOMETRIC HEIGHT PUBLICATION SOURCE	PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.
ELEVATION — ELEVATION IN US SVY FEET	N/A
ELEVATION IN METERS	N/A
ELEVATION DATUM	N/A
ELEVATION POSITIONAL QUALITY	N/A
ELEVATION PUBLICATION SOURCE	N/A

FDOT D5 PID

90501004

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:34:58 P

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GPS OBSERVATION POTENTIAL: GOOD

STATION VISITATION SAFETY CONSIDERATION

NO OBSERVED EXTRAORDINARY SAFETY CONSIDERATIONS REPORTED FOR THIS STATION SITE.

DESCRIPTION OF STATION MONUMENT - DISK / CAP AND STAMPINGS

MONUMENT CONSTRUCTION: CONCRETE SIDEWALK
MONUMENT CONDITION: GOOD
DISK/CAP LOCATION ON MONUMENT: FLUSH ON TOP
DISK/CAP SETTING: DRILL HOLE AND EPOXY
DISK/CAP CONSTRUCTION: MAG NAIL AND 1.5" STEEL WASHER
DISK/CAP OCCUPATION POINT: DIMPLE IN CENTER OF NAIL HEAD
DISK/CAP CASTING STAMP: [MAG]
DISK/CAP HAND STAMPING: [D5PNC] [90501004]
DISK/CAP CONDITION: GOOD
DISK/CAP STABILITY: GOOD

STATION SITE "TO REACH" DESCRIPTION

PPHCN 90501 90501004 FIELD STATION REPORT, DATED 2005.12.21. (ALL DISTANCES ARE APPROXIMATE)
AT THE INTERSECTION OF S.R. 44 (NEW YORK AVE.) AND S.R. 15A (SPRING GARDEN AVE.), PROCEED EASTERLY ALONG S.R. 44 (NEW YORK AVE.) FOR 1.0 MILES TO THE STATION ON THE RIGHT. STATION IS AT THE INTERSECTION OF S.R.44 (NEW YORK AVE.) AND CLARA AVE. STATION IS IN THE SOUTHEAST QUADRANT OF THE INTERSECTION IN A CONCRETE SIDEWALK.

REFERENCE OBJECTS: PPHCN 90501 90501004 FIELD STATION REPORT, DATED 2005.12.21.
S 81 W 11.8 FT. MAST ARM STEEL COLUMN
S 82 E 23.6 FT. POWER POLE, WOOD, NO # ,MAG NAIL AND [FDOT REF.] DISK
S 10 W 75.5 FT. NW-CORNER OF POST OFFICE BLDG.
N 00 E 8.2 FT. BACK OF CONCRETE CURB

SURVEY BASELINE STATION PLUS	SURVEY BASELINE STATION OFFSET	US SVY FT	METERS
N/A	N/A	☐	☐

SOR BASELINE DESCRIPTION PUBLICATION SOURCE

N/A

STATION HISTORY

ASSOCIATED MEDIA FILES: AVAILABLE ON CD.

2006.10.25 BY J. HAWKINS OF FDOT D5 STAFF, REPORTING ON PPHCN 90501, F.P. NO.4046461.
STATION MONUMENTED: YES. DECEMBER 2005. (FDOT)
STATION OCCUPIED : YES.
NETWORK NAME : 90501 90501004
STATION ALIAS: N/A
EFB NAME: N/A

LATITUDE : ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83 (1990).
LONGITUDE: ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83 (1990).
ELLIPSOID HEIGHT: ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83.
GPS NGVD 29 ELEVATION: NOT ESTABLISHED.
GPS NAVD 88 ORTHOMETRIC HEIGHT: ESTABLISHED. PPHNC.
LEVELED NGVD 29 ELEVATION: NOT ESTABLISHED.
LEVELED NGVD 88 ORTOMETRIC HEIGHT: NOT ESTABLISHED.

NOTE: STATION PHOTOGRAPHY TAKEN

NOTE: "XY" ESTABLISHED LATITUDE/LONGITUDE IN NETWORK.
NOTE: "H" ESTABLISHED ELLIPSOID HEIGHT IN NETWORK. 90501_RPT03.TXT, DATED 2006.11.28.
NOTE: "h" ESTABLISHED GPS NAVD 88 ORTHOMETRIC HEIGHT IN NETWORK.

FINAL NETWORK ADJUSTMENT REPORT: 90501_RPT12.TXT, DATED 2006.11.28.

FDOT D5 PID

90501004

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:34:58 P

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****

FLORIDA DEPARTMENT OF TRANSPORTATION DISTRICT FIVE LOCATION SURVEY SECTION
STATION SITE OBSTRUCTION MASKING REPORT

PAGE 1 OF ___ DATE: 2005.____.____

FIELD PARTY: J. HAWKIN, F. TAYLOR, A. NEWCOMB

FULL NETWORK STATION NAME: 09 05 01 004 FDOTD5 PID: 90501004

HAND HELD CLINOMETER: YES ✓ NO ___ HAND HELD COMPASS: YES ✓ NO ___

OTHER ___

H.I. MEASURED WITH: FOLDING RULE

OBSTRUCTIONS OBSERVED AT H.I. OF 1.790 m ABOVE NORMAL GROUND AT STATION SITE.

STATION MARK IS 0.00 METERS ABOVE ___ BELOW ✓ NORMAL GROUND AT STATION SITE.

H = AZIMUTH ANGLE FROM MAGNETIC NORTH AS DETERMINED BY HAND COMPASS. FULL CIRCLE SWEEP.
V = ANGLE OF ELEVATION FROM THE APPARENT HORIZON AT THE INSTRUMENT OBSERVATION HEIGHT

BEGIN OBSTRUCTION H	V		END OBSTRUCTION H	V	OBSTRUCTION DESCRIPTION
0	15	TO	254	15	NO OBSTRUCTION
254	30	TO	273	30	TREE LINE
273	15	TO	360	15	NO OBSTRUCTION
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			

COMMENTS

FDOT D5 PID: 90501006

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, April 24, 2008 3:21:01 PM

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HECTOR_NAME: 90501006
EFB_NAME: N/A
3WIRE_NAME: N/A

GOT_VECTOR: ☑
GOT_LEVEL: ☐

DESTROYED STATION ☐
ELE STATION ☐
REVIEWED ☑
LOST STATION ☐
NOT CONNECTED ☐

PRECISE LATITUDE / LONGITUDE

LATITUDE	29	01	41.60855
LONGITUDE	81	17	57.09887

APPROXIMATE LATITUDE / LONGITUDE

LATITUDE	N/A	N/A	N/A
LONGITUDE	N/A	N/A	N/A

LATITUDE / LONGITUDE POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

LATITUDE / LONGITUDE REFERENCE DATUM: NAD 83 (1990)

LATITUDE / LONGITUDE PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

ELLIPSOID HEIGHT IN US SVY FEET: -39.5488
ELLIPSOID HEIGHT IN METERS: -12.0545
ELLIPSOID HEIGHT REFERENCE DATUM: NAD 83

ELLIPSOID HEIGHT POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

ELLIPSOID HEIGHT PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

SPC - NORTHING US SVY FEET: 1706673.3718
SPC - NORTHING METERS: 520195.0841
STATE PLANE PROJECTION SCALE FACTOR: .99995165

SPC - EASTING US SVY FEET: 560551.4301
SPC - EASTING METERS: 170856.4176
STATE PLANE ZONE: FLORIDA EAST

STATE PLANE COORDINATE POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

STATE PLANE PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

DIFFERENTIALLY LEVELED ORTHOMETRIC HEIGHT
DL ORTHOMETRIC HEIGHT IN US SVY FEET: N/A
DL ORTHOMETRIC HEIGHT IN METERS: N/A

ORTHOMETRIC HEIGHT DATUM: NAVD 88

GPS DERIVED ORTHOMETRIC HEIGHT
GPS ORTHO HEIGHT IN US SVY FEET: 52.0685
GPS ORTHO HEIGHT IN METERS: 15.8705

ORTHOMETRIC HEIGHT POSITIONAL QUALITY: APPROXIMATE BY GPS NETWORK OBSERVATIONS

ORTHOMETRIC HEIGHT PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

ELEVATION
ELEVATION IN US SVY FEET: N/A
ELEVATION IN METERS: N/A
ELEVATION DATUM: N/A

ELEVATION POSITIONAL QUALITY: N/A

ELEVATION PUBLICATION SOURCE: N/A

FDOT D5 PID

90501006

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
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Thursday, April 24, 2008 3:21:01 PM

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GPS OBSERVATION POTENTIAL: GOOD

STATION VISITATION SAFETY CONSIDERATION

NO OBSERVED EXTRAORDINARY SAFETY CONSIDERATIONS REPORTED FOR THIS STATION SITE.

DESCRIPTION OF STATION MONUMENT - DISK / CAP AND STAMPINGS

MONUMENT CONSTRUCTION: CONCRETE SIDEWALK
MONUMENT CONDITION: GOOD
DISK/CAP LOCATION ON MONUMENT: FLUSH ON TOP
DISK/CAP SETTING: DRILL HOLE AND EPOXY
DISK/CAP CONSTRUCTION: MAG NAIL AND 1.5" STEEL WASHER
DISK/CAP OCCUPATION POINT: DIMPLE IN CENTER OF NAIL HEAD
DISK/CAP CASTING STAMP: [MAG]
DISK/CAP HAND STAMPING: [D5PNC] [90501006]
DISK/CAP CONDITION: GOOD
DISK/CAP STABILITY: GOOD

STATION SITE "TO REACH" DESCRIPTION

PPHCN 90501 90501006 FIELD STATION REPORT, DATED 2005.12.21. (ALL DISTANCES ARE APPROXIMATE)
AT THE INTERSECTION OF S.R. 44 (NEW YORK AVE.) AND S.R. 15A (SPRING GARDEN AVE.), PROCEED EASTERLY ALONG S.R. 44 (NEW YORK AVE.) FOR 1.5 MILES TO THE STATION ON THE LEFT. STATION IS AT THE INTERSECTION OF S.R. 44 (NEW YORK AVE.) AND AMELIA AVENUE STATION IS IN THE NORTHEAST QUADRANT OF THE INTERSECTION IN A CONCRETE SIDEWALK.

REFERENCE OBJECTS: PPHCN 90501 90501006 FIELD STATION REPORT, DATED 2005.12.21.
N 80 W 4.0 FT. E-EOP, N. AMELIA AVE., N-BOUND LANES, MAG NAIL AND [FDOT REF] DISK
S 75 E 13.0 FT. 12" PALM TREE, MAG NAIL AND [FDOT REF] DISK
S 20 E 20.8 FT. STEEL MAST ARM SUPPORT COLUMN
N 00 E 86.1 FT. METAL SIGN, "NO LEFT TURN"

SURVEY BASELINE STATION PLUS: N/A

SURVEY BASELINE STATION OFFSET: N/A

US SVY FT ☐ METERS ☐

SOR BASELINE DESCRIPTION PUBLICATION SOURCE

N/A

STATION HISTORY

ASSOCIATED MEDIA FILES: AVAILABLE ON CD.

2006.10.25 BY J. HAWKINS OF FDOT D5 STAFF, REPORTING ON PPHCN 90501, F.P. NO.4046461.
STATION MONUMENTED: YES. DECEMBER 2005. (FDOT)
STATION OCCUPIED : YES.
NETWORK NAME : 90501 90501006
STATION ALIAS: N/A
EFB NAME: N/A

LATITUDE : ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83 (1990).
LONGITUDE: ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83 (1990).
ELLIPSOID HEIGHT: ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83.
GPS NGVD 29 ELEVATION: NOT ESTABLISHED.
GPS NAVD 88 ORTHOMETRIC HEIGHT: ESTABLISHED. PPHNC.
LEVELED NGVD 29 ELEVATION: NOT ESTABLISHED.
LEVELED NGVD 88 ORTOMETRIC HEIGHT: NOT ESTABLISHED.

NOTE: STATION PHOTOGRAPHY TAKEN

NOTE: "XY" ESTABLISHED LATITUDE/LONGITUDE IN NETWORK.
NOTE: "H" ESTABLISHED ELLIPSOID HEIGHT IN NETWORK. 90501_RPT03.TXT, DATED 2006.11.27.
NOTE: "h" ESTABLISHED GPS NAVD 88 ORTHOMETRIC HEIGHT IN NETWORK.

FINAL NETWORK ADJUSTMENT REPORT: 90501_RPT12.TXT, DATED 2006.11.28.

FDOT D5 PID

90501006

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, April 24, 2008 3:21:01 PM

DATA PROVIDED IS FOR INFORMATIONAL PURPOSES ONLY. DATA IS SUBJECT TO CHANGE AND REVISION WITHOUT NOTICE TO THE USER. USER ASSUMES ALL RISK AND LIABILITY FROM DATA USAGE UNLESS AUTHORIZED OTHERWISE BY FDOT.

DUE TO THE USE OF AUTOMATED IMPORTATION PROCESSES INTO THE PNC DATABASE THE PUBLISHED VALUES AS DEPICTED IN THIS REPORT MAY BE EXPRESSED AT A HIGHER PRECISION THAN ACTUALLY DETERMINED. PLEASE REFER TO THE POSITIONAL QUALITY STATEMENT FOR EACH PUBLISHED COMPONENT TO DETERMINE APPROPRIATE USAGE PRECISIONS.

```
*****************************************************************************************************

2008.04.11 BY D. SARACINA OF D5 FDOT STAFF, REPORTING ON FP 4220242.
STATION RECOVERED: YES. APRIL 2008. (FDOT) GOOD CONDITION
STATION NAME: 90501006

NOTE: STATION RESEARCHED FOR POSSIBLE USE - NON PNC HORIZONTAL. RECOVERY DATA PROVIDED TO LOCHRANE.
NOTE: NO FURTHER UPDATE TO RECORD.
*****************************************************************************************************
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FLORIDA DEPARTMENT OF TRANSPORTATION DISTRICT FIVE LOCATION SURVEY SECTION
STATION SITE OBSTRUCTION MASKING REPORT

PAGE 1 OF ___ DATE: 2005. 12 . 21

FIELD PARTY: J. HAWKIN, F. TAYLOR, A. NEWCOMB

FULL NETWORK STATION NAME: 09 05 01 006 FDOTD5 PID: 90501006

HAND HELD CLINOMETER: YES ✓ NO ______ HAND HELD COMPASS: YES ✓ NO ______

OTHER ______

H.I. MEASURED WITH: FOLDING RULE

OBSTRUCTIONS OBSERVED AT H.I. OF 1.790 m ABOVE NORMAL GROUND AT STATION SITE.

STATION MARK IS 0.00 METERS ABOVE ___ BELOW ✓ NORMAL GROUND AT STATION SITE.

H = AZIMUTH ANGLE FROM MAGNETIC NORTH AS DETERMINED BY HAND COMPASS. FULL CIRCLE SWEEP.
V = ANGLE OF ELEVATION FROM THE APPARENT HORIZON AT THE INSTRUMENT OBSERVATION HEIGHT

BEGIN OBSTRUCTION H	BEGIN OBSTRUCTION V		END OBSTRUCTION H	END OBSTRUCTION V	OBSTRUCTION DESCRIPTION
0	15	TO	8	15	NO OBSTRUCTION.
8	22	TO	35	22	BIDG.
35	15	TO	75	15	NO OBSTRUCTION
75	60	TO	129	60	TREELINE
129	15	TO	360	15	NO OBSTRUCTION
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			
		TO			

COMMENTS

FDOT D5 PID: 90501007

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:47:55 P

DATA PROVIDED IS FOR INFORMATIONAL PURPOSES ONLY. DATA IS SUBJECT TO CHANGE AND REVISION WITHOUT NOTICE TO THE USER. USER ASSUMES ALL RISK AND LIABILITY FROM DATA USAGE UNLESS AUTHORIZED OTHERWISE BY FDOT.

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HECTOR_NAME: 90501007
GOT_VECTOR: ☑

EFB_NAME: N/A

3WIRE_NAME: N/A
GOT_LEVEL: ☐

PRECISE LATITUDE / LONGITUDE
LATITUDE: 29 | 01 | 41.08043
LONGITUDE: 81 | 17 | 27.14181

DESTROYED STATION ☐
ELE STATION ☐
REVIEWED ☑
LOST STATION ☐
NOT CONNECTED ☐

APPROXIMATE LATITUDE / LONGITUDE
LATITUDE: N/A | N/A | N/A
LONGITUDE: N/A | N/A | N/A

LATITUDE / LONGITUDE POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

LATITUDE / LONGITUDE REFERENCE DATUM: NAD 83 (1990)

LATITUDE / LONGITUDE PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

ELLIPSOID HEIGHT IN US SVY FEET: -22.5295

ELLIPSOID HEIGHT IN METERS: -6.8670

ELLIPSOID HEIGHT REFERENCE DATUM: NAD 83

ELLIPSOID HEIGHT POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

ELLIPSOID HEIGHT PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

SPC - NORTHING US SVY FEET: 1706613.3847

SPC - NORTHING METERS: 520176.8000

STATE PLANE PROJECTION SCALE FACTOR: .99995108

SPC - EASTING US SVY FEET: 563210.6324

SPC - EASTING METERS: 171666.9441

STATE PLANE ZONE: FLORIDA EAST

STATE PLANE COORDINATE POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

STATE PLANE PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

DIFFERENTIALLY LEVELED ORTHOMETRIC HEIGHT
DL ORTHOMETRIC HEIGHT IN US SVY FEET: N/A
DL ORTHOMETRIC HEIGHT IN METERS: N/A

ORTHOMETRIC HEIGHT DATUM: NAVD 88

GPS DERIVED ORTHOMETRIC HEIGHT
GPS ORTHO HEIGHT IN US SVY FEET: 69.0878
GPS ORTHO HEIGHT IN METERS: 21.0580

ORTHOMETRIC HEIGHT POSITIONAL QUALITY: APPROXIMATE BY GPS NETWORK OBSERVATIONS

ORTHOMETRIC HEIGHT PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

ELEVATION
ELEVATION IN US SVY FEET: N/A
ELEVATION IN METERS: N/A
ELEVATION DATUM: N/A

ELEVATION POSITIONAL QUALITY: N/A

ELEVATION PUBLICATION SOURCE: N/A

FDOT D5 PID

90501007

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:47:55 P

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GPS OBSERVATION POTENTIAL: GOOD

STATION VISITATION SAFETY CONSIDERATION

NO OBSERVED EXTRAORDINARY SAFETY CONSIDERATIONS REPORTED FOR THIS STATION SITE.

DESCRIPTION OF STATION MONUMENT - DISK / CAP AND STAMPINGS

MONUMENT CONSTRUCTION: CONCRETE SIDEWALK
MONUMENT CONDITION: GOOD
DISK/CAP LOCATION ON MONUMENT: FLUSH ON TOP
DISK/CAP SETTING: DRILL HOLE AND EPOXY
DISK/CAP CONSTRUCTION: MAG NAIL AND 1.5" STEEL WASHER
DISK/CAP OCCUPATION POINT: DIMPLE IN CENTER OF NAIL HEAD
DISK/CAP CASTING STAMP: [MAG]
DISK/CAP HAND STAMPING: [FDOT] [REF]
DISK/CAP CONDITION: GOOD
DISK/CAP STABILITY: GOOD

STATION SITE "TO REACH" DESCRIPTION

PPHCN 90501 90501007 FIELD STATION REPORT, DATED 2005.12.21. (ALL DISTANCES ARE APPROXIMATE)
AT THE INTERSECTION OF S.R. 44 (NEW YORK AVE.) AND S.R. 15A (SPRING GARDEN AVE.), PROCEED EASTERLY ALONG S.R. 44 (NEW YORK AVE.) FOR 2.0 MILES TO THE STATION ON THE RIGHT. STATION IS AT THE INTERESECTION OF S.R. 44 (NEW YORK AVE.) AND BOSTON AVENUE IN THE SOUTHEAST QUADRANT IN A CONCRETE SIDEWALK.

REFERENCE OBJECTS: PPHCN 90501 90501007 FIELD STATION REPORT, DATED 2005.12.21.
S 67 E 20.2 FT. 10" PALM TREE, MAG NAIL AND [FDOT REF.] DISK
S 28 E 55.7 FT. NW-CORNER OF BRICK BLDG. #702 E. NEW YORK AVE.
S 00 W 65.6 FT. POWER POLE, WOOD, NO #, MAG NAIL AND [FDOT REF.] DISK
N 06 E 6.6 FT. BACK OF CONCRETE CURB

SURVEY BASELINE STATION PLUS	SURVEY BASELINE STATION OFFSET	US SVY FT	METERS
N/A	N/A	☐	☐

SOR BASELINE DESCRIPTION PUBLICATION SOURCE

N/A

STATION HISTORY

ASSOCIATED MEDIA FILES: AVAILABLE ON CD.

2006.10.25 BY J. HAWKINS OF FDOT D5 STAFF, REPORTING ON PPHCN 90501, F.P. NO.4046461.
STATION MONUMENTED: YES. DECEMBER 2005. (FDOT)
STATION OCCUPIED : YES.
NETWORK NAME : 90501 90501007
STATION ALIAS: N/A
EFB NAME: N/A

LATITUDE : ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83 (1990).
LONGITUDE: ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83 (1990).
ELLIPSOID HEIGHT: ESTABLISHED. PPHNC. GPS OBSERVATION. NAD 83.
GPS NGVD 29 ELEVATION: NOT ESTABLISHED.
GPS NAVD 88 ORTHOMETRIC HEIGHT: ESTABLISHED. PPHNC.
LEVELED NGVD 29 ELEVATION: NOT ESTABLISHED.
LEVELED NGVD 88 ORTOMETRIC HEIGHT: NOT ESTABLISHED.

NOTE: STATION PHOTOGRAPHY TAKEN

NOTE: "XY" ESTABLISHED LATITUDE/LONGITUDE IN NETWORK.
NOTE: "H" ESTABLISHED ELLIPSOID HEIGHT IN NETWORK. 90501_RPT03.TXT, DATED 2006.11.27.
NOTE: "h" ESTABLISHED GPS NAVD 88 ORTHOMETRIC HEIGHT IN NETWORK.

FINAL NETWORK ADJUSTMENT REPORT: 90501_RPT12.TXT, DATED 2006.11.28.

FDOT D5 PID

90501007

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:47:55 P

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FLORIDA DEPARTMENT OF TRANSPORTATION DISTRICT FIVE LOCATION SURVEY SECTION
STATION SITE OBSTRUCTION MASKING REPORT

PAGE 1 OF ___ DATE: 2005. 12 . 21

FIELD PARTY: J. HAWKIN, F. TAYLOR, A. NEWCOMB

FULL NETWORK STATION NAME: 09 05 01 007 FDOTD5 PID: 90501007

HAND HELD CLINOMETER: YES ✓ NO ____ HAND HELD COMPASS: YES ✓ NO ____

OTHER ____

H.I. MEASURED WITH: FOLDING RULE

OBSTRUCTIONS OBSERVED AT H.I. OF 1.790 m ABOVE NORMAL GROUND AT STATION SITE.

STATION MARK IS 0.00 METERS ABOVE ___ BELOW ✓ NORMAL GROUND AT STATION SITE.

H = AZIMUTH ANGLE FROM MAGNETIC NORTH AS DETERMINED BY HAND COMPASS. FULL CIRCLE SWEEP.
V = ANGLE OF ELEVATION FROM THE APPARENT HORIZON AT THE INSTRUMENT OBSERVATION HEIGHT

BEGIN OBSTRUCTION			END OBSTRUCTION		OBSTRUCTION DESCRIPTION
0 H	15 V	TO	360 H	15 V	NO OBSTRUCTION
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	

COMMENTS

FDOT D5 PID: VOLV119

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:33:12 P

DATA PROVIDED IS FOR INFORMATIONAL PURPOSES ONLY. DATA IS SUBJECT TO CHANGE AND REVISION WITHOUT NOTICE TO THE USER. USER ASSUMES ALL RISK AND LIABILITY FROM DATA USAGE UNLESS AUTHORIZED OTHERWISE BY FDOT.

DUE TO THE USE OF AUTOMATED IMPORTATION PROCESSES INTO THE PNC DATABASE THE PUBLISHED VALUES AS DEPICTED IN THIS REPORT MAY BE EXPRESSED AT A HIGHER PRECISION THAN ACTUALLY DETERMINED. PLEASE REFER TO THE POSITIONAL QUALITY STATEMENT FOR EACH PUBLISHED COMPONENT TO DETERMINE APPROPRIATE USAGE PRECISIONS.

HECTOR_NAME: VOLV119
GOT_VECTOR: ☑
EFB_NAME: N/A
3WIRE_NAME: N/A
GOT_LEVEL: ☐

PRECISE LATITUDE / LONGITUDE
LATITUDE: 29 | 01 | 39.47420
LONGITUDE: 81 | 20 | 11.51242

DESTROYED STATION ☐
ELE STATION ☐
REVIEWED ☑
LOST STATION ☐
NOT CONNECTED ☐

APPROXIMATE LATITUDE / LONGITUDE
LATITUDE: N/A | N/A | N/A
LONGITUDE: N/A | N/A | N/A

LATITUDE / LONGITUDE POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

LATITUDE / LONGITUDE REFERENCE DATUM: NAD 83 (1990)

LATITUDE / LONGITUDE PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

ELLIPSOID HEIGHT IN US SVY FEET: -29.2394
ELLIPSOID HEIGHT IN METERS: -8.9122
ELLIPSOID HEIGHT REFERENCE DATUM: NAD 83

ELLIPSOID HEIGHT POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

ELLIPSOID HEIGHT PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

SPC - NORTHING US SVY FEET: 1706489.9135
SPC - NORTHING METERS: 520139.1659
STATE PLANE PROJECTION SCALE FACTOR: .99995443

SPC - EASTING US SVY FEET: 548618.7098
SPC - EASTING METERS: 167219.3172
STATE PLANE ZONE: FLORIDA EAST

STATE PLANE COORDINATE POSITIONAL QUALITY: PPHNC BY GPS NETWORK OBSERVATIONS

STATE PLANE PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

DIFFERENTIALLY LEVELED ORTHOMETRIC HEIGHT
DL ORTHOMETRIC HEIGHT IN US SVY FEET: N/A
DL ORTHOMETRIC HEIGHT IN METERS: N/A

ORTHOMETRIC HEIGHT DATUM: NAVD 88

GPS DERIVED ORTHOMETRIC HEIGHT
GPS ORTHO HEIGHT IN US SVY FEET: 62.3942
GPS ORTHO HEIGHT IN METERS: 19.0178

ORTHOMETRIC HEIGHT POSITIONAL QUALITY: APPROXIMATE BY GPS NETWORK OBSERVATIONS

ORTHOMETRIC HEIGHT PUBLICATION SOURCE: PPHNC 90501. 90501_RPT12.TXT, DATED 2006.11.28.

ELEVATION
ELEVATION IN US SVY FEET: N/A
ELEVATION IN METERS: N/A
ELEVATION DATUM: N/A

ELEVATION POSITIONAL QUALITY: N/A

ELEVATION PUBLICATION SOURCE: N/A

FDOT D5 PID

VOLV119

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:33:12 P

GPS OBSERVATION POTENTIAL: POOR

STATION VISITATION SAFETY CONSIDERATION

NO OBSERVED EXTRAORDINARY SAFETY CONSIDERATIONS REPORTED FOR THIS STATION SITE.

DESCRIPTION OF STATION MONUMENT - DISK / CAP AND STAMPINGS

```
MONUMENT CONSTRUCTION: 10" DIAMETER POURED IN PLACE CONCRETE MONUMENT
MONUMENT CONDITION: GOOD
DISK/CAP LOCATION ON MONUMENT: CENTERED ON TOP
DISK/CAP SETTING: SET WHEN CAST
DISK/CAP CONSTRUCTION: 3" DIAMETER STEINMAN ALUMINUM SURVEY DISK
DISK/CAP OCCUPATION POINT: DIMPLE IN CENTER OF RAISED TRIANGLE
DISK/CAP CASTING STAMP: [COUNTY OF VLOUSIA] [1991 GPS CONTROL] [LB1701] [STEINMAN & ASSCO]
DISK/CAP HAND STAMPING: [V119]
DISK/CAP CONDITION: GOOD
DISK/CAP STABILITY: GOOD
```

STATION SITE "TO REACH" DESCRIPTION

```
PPHCN 90501 VOLV119 FIELD STATION REPORT, DATED 2005.12.19. (ALL DISTANCES ARE APPROXIMATE)
AT THE INTERSECTION OF S.R. 44 (NEW YORK AVE.) AND S.R. 15A (SPRING GARDEN AVE.), PROCEED WESTERLY
ALONG S.R. 44 (NEW YORK AVE.) FOR 0.7 MILES TO THE STATION ON THE LEFT. STATION IS IN A GRASS MEDIAN
BETWEEN S.R. 44 (NEW YORK AVE.) AND OLD NEW YORK AVENUE AND IS 16.9 FT. SOUTH OF THE SOUTH EDGE OF
PAVEMENT OF S.R. 44 (NEW YORK AVE.).

REFERENCE OBJECTS: PPHCN 90501 VOLV119 FIELD STATION REPORT, DATED 2005.12.19.
S 42 W   61.2 FT.  N-EOP, OLD NEW YORK AVE. PK NAIL AND PCP [LB1701]
S 85 E   31.7 FT.  POWER POLE, WOOD, #785606, MAG NAIL AND [FDOT REF.] DISK
N 05 E   16.9 FT.  S-EOP, S.R. 44 (NEW YORK AVE.) MAG NAIL AND [FDOT REF.] DISK
N 76 W   32.2 FT.  MITRED END SECTION, NW-CORNER
S 05 W    3.0 FT.  COMPOSITE RESIN POST WITH DECAL
```

SURVEY BASELINE STATION PLUS	SURVEY BASELINE STATION OFFSET	US SVY FT	METERS
N/A	N/A	☐	☐

SOR BASELINE DESCRIPTION PUBLICATION SOURCE

N/A

STATION HISTORY

ASSOCIATED MEDIA FILES: AVAILABLE ON CD.

```
2007.01.11 BY D. SARACINAS OF FDOT D5 STAFF, REPORTING ON INITIAL PUBLICATION SOURCE.
INITIAL PUBLICATION SOURCE IS THE 1990 VOLUSIA COUNTY DENSIFICATION PROJECT BY KEITH AND SCHNARS.
GPS AZIMUTH MARK, GPS STATION DATA FORM, STEINMAN & ASSOCIATES.
THIS IS A NON BLUE BOOKED AZIMUTH STATION.
STATION MONUMENTED: SEPTEMBER 1991. (STEINMAN & ASSOC.)
STATION NAME : V119
STATION ALIAS: UNKNOWN

LATITUDE : ESTABLISHED. BY GPS OBSERVATIONS. NAD 83 (1990).
LONGITUDE: ESTABLISHED. BY GPS OBSERVATIONS. NAD 83 (1990).
ELLIPSOID HEIGHT: NOT REPORTED.
GPS NGVD 29 ELEVATION: NOT REPORTED.
GPS NAVD 88 ORTHOMETRIC HEIGHT: NOT REPORTED.
LEVELED NGVD 29 ELEVATION: NOT REPORTED
LEVELED NAVD 88 ORTHOMETRIC HEIGHT: NOT REPORTED.
******************************************************************************************************

2006.03.01 BY J. HAWKINS OF FDOT D5 STAFF, REPORTING ON PPHCN 90501, F.P. NO.4046461.
STATION RECOVERED: YES. DECEMBER 2005. (FDOT)
STATION OCCUPIED : YES.
NETWORK NAME : 90501 VOLV119
```

FDOT D5 PID

VOLV119

PNC STATION REPORT
FDOT D5 LOCATION SURVEY
PNC WORK GROUP

Thursday, January 11, 2007 2:33:12 P

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```
STATION ALIAS: V119 STEINMAN & ASSOC.
EFB NAME: N/A

LATITUDE : UNCHANGED.
LONGITUDE: UNCHANGED.
ELLIPSOID HEIGHT: ESTABLISHED. GPS OBSERVATIONS.
GPS NGVD 29 ELEVATION: N/A
GPS NAVD 88 ORTHOMETRIC HEIGHT: ESTABLISHED.
LEVELED NGVD 29 ELEVATION: N/A
LEVELED NGVD 88 ORTOMETRIC HEIGHT: N/A

NOTE: STATION PHOTOGRAPHY TAKEN

NOTE: "XY" HELD LATITUDE/LONGITUDE FIXED PER 1990 VOL. CO. DENSIFICATION PROJECT, STEINMAN & ASSOC.
NOTE: GPS STATION DATA SHEET, DATED DECEMBER 1991.
NOTE "H" ESTABLISHEDD ELLIPSOID HEIGHT IN NETWORK. 90501_RPT03.TXT, DATED 2006.11.27.
NOTE "h" ESTABLISHED GPS NAVD 88 ORTHOMETRIC HEIGHT IN NETWORK. 90501_RPT12.TXT, DATED 2006.11.28.

FINAL NETWORK ADJUSTMENT REPORT: 90501_RPT12.TXT, DATED 2006.11.28.
******************************************************************************************************
```

FLORIDA DEPARTMENT OF TRANSPORTATION DISTRICT FIVE LOCATION SURVEY SECTION
STATION SITE OBSTRUCTION MASKING REPORT

PAGE 1 OF ___ DATE: 2005. 12 . 19

FIELD PARTY: J. HAWKIN, F. TAYLOR, A. NEWCOMB

FULL NETWORK STATION NAME: 09 05 01 VOL.V119 FDOTD5 PID: VOL V119

HAND HELD CLINOMETER: YES ✓ NO ___ HAND HELD COMPASS: YES ✓ NO ___

OTHER ___

H.I. MEASURED WITH: ___

OBSTRUCTIONS OBSERVED AT H.I. OF 1.790 m ABOVE NORMAL GROUND AT STATION SITE.

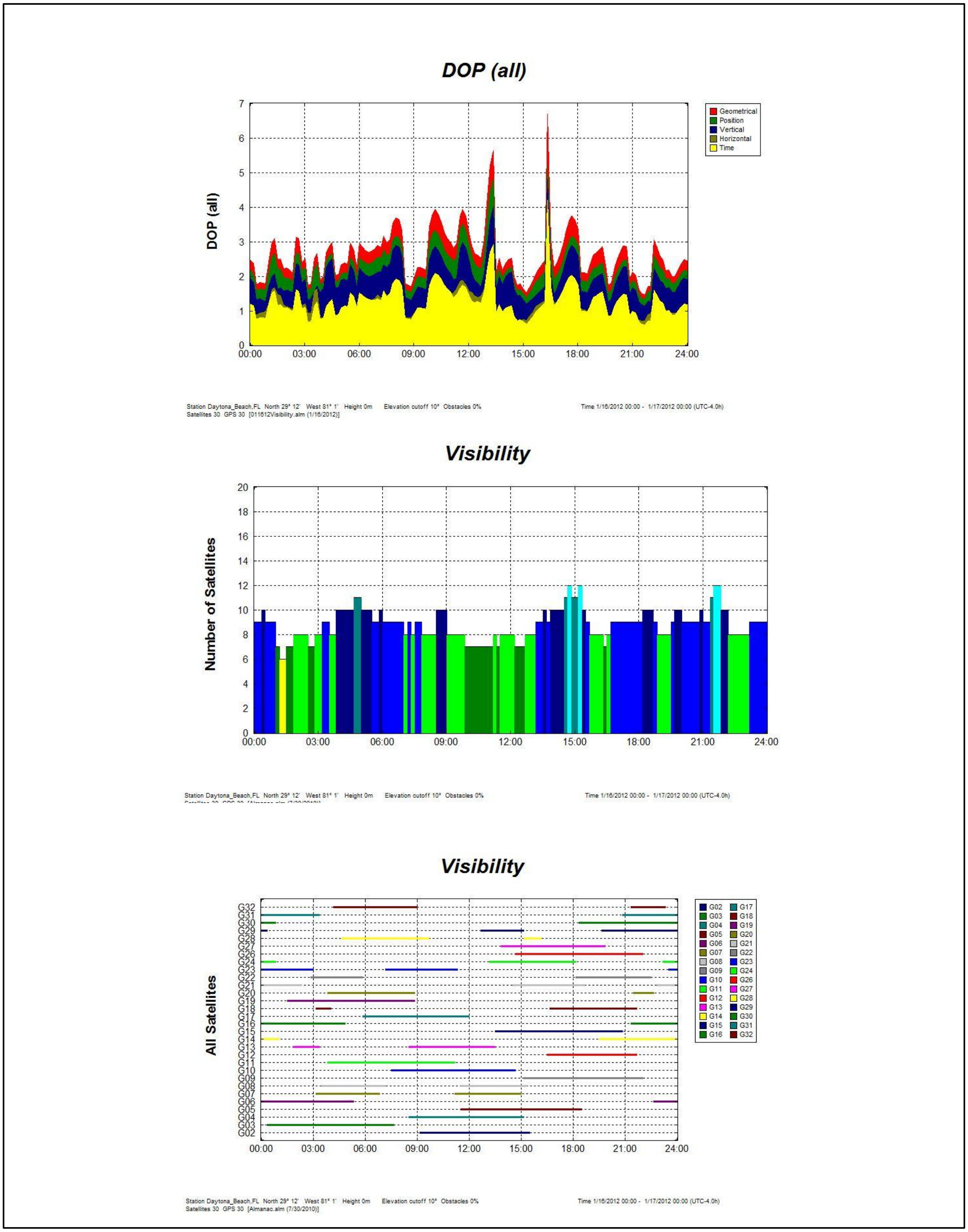
STATION MARK IS 0.00 METERS ABOVE ___ BELOW ✓ NORMAL GROUND AT STATION SITE.

H = AZIMUTH ANGLE FROM MAGNETIC NORTH AS DETERMINED BY HAND COMPASS. FULL CIRCLE SWEEP.
V = ANGLE OF ELEVATION FROM THE APPARENT HORIZON AT THE INSTRUMENT OBSERVATION HEIGHT

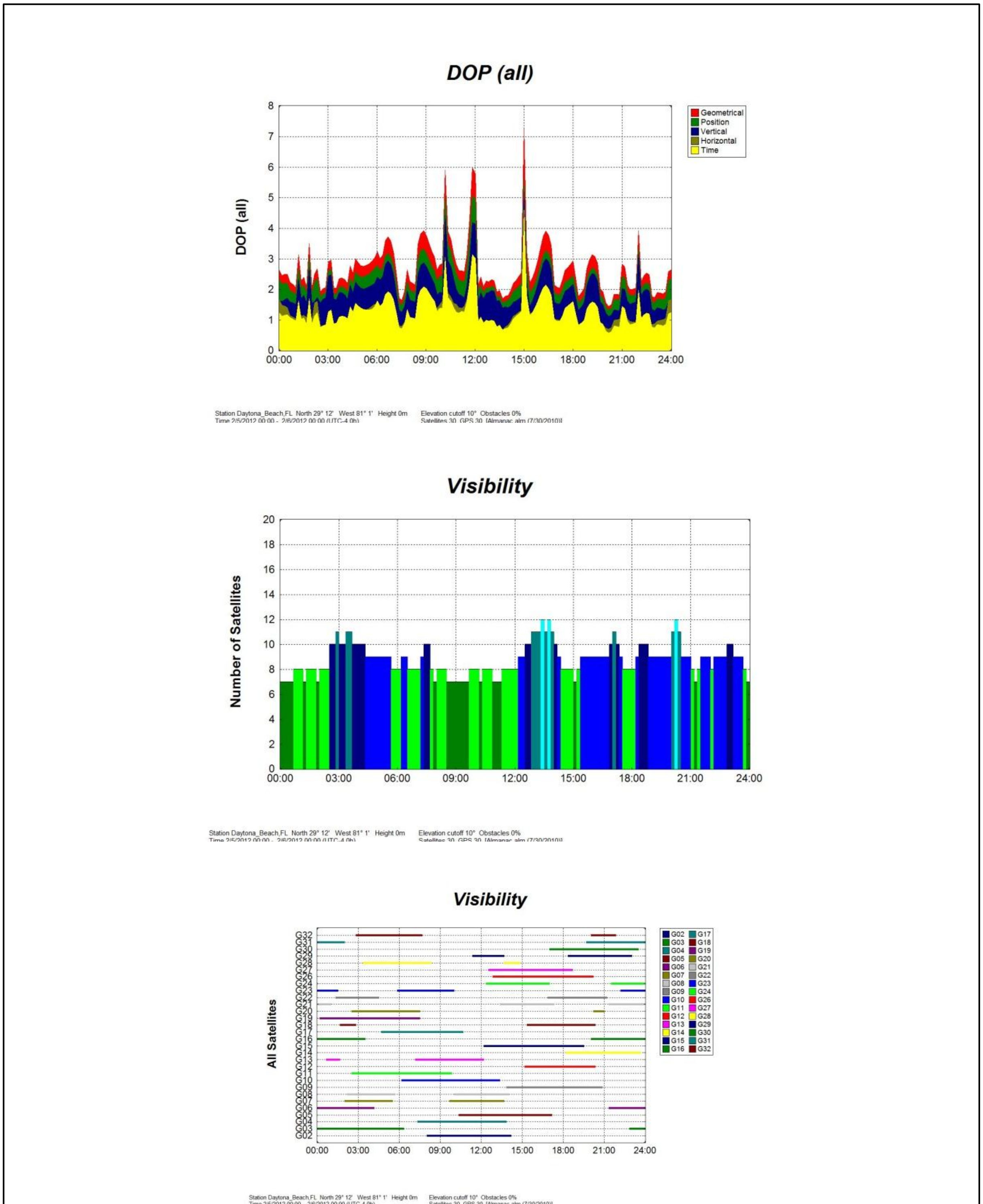
BEGIN OBSTRUCTION H	V		END OBSTRUCTION H	V	OBSTRUCTION DESCRIPTION
0 H	30 V	TO	5 H	30 V	TREE LINE
5 H	15 V	TO	12 H	15 V	NO OBSTRUCTION
12 H	22 V	TO	82 H	22 V	TREE LINE
82 H	15 V	TO	110 H	15 V	NO OBSTRUCTION
110 H	26 V	TO	270 H	26 V	TREE LINE
270 H	15 V	TO	297 H	15 V	NO OBSTRUCTION
297 H	24 V	TO	323 H	24 V	TREE LINE
323 H	15 V	TO	330 H	15 V	NO OBSTRUCTION
330 H	30 V	TO	360 H	30 V	TREE LINE
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	
H	V	TO	H	V	

COMMENTS

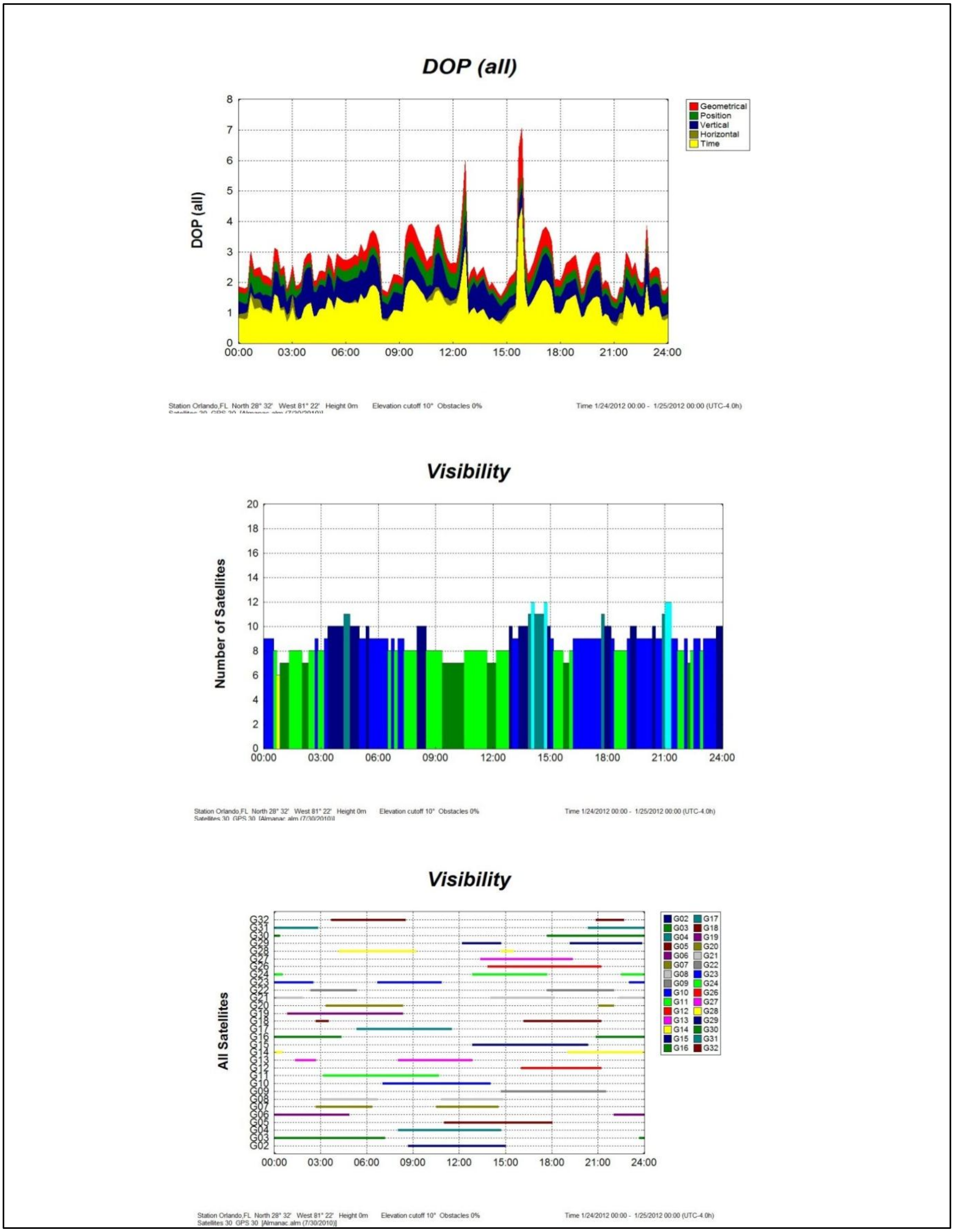
APPENDIX B: PLANNING MATERIAL



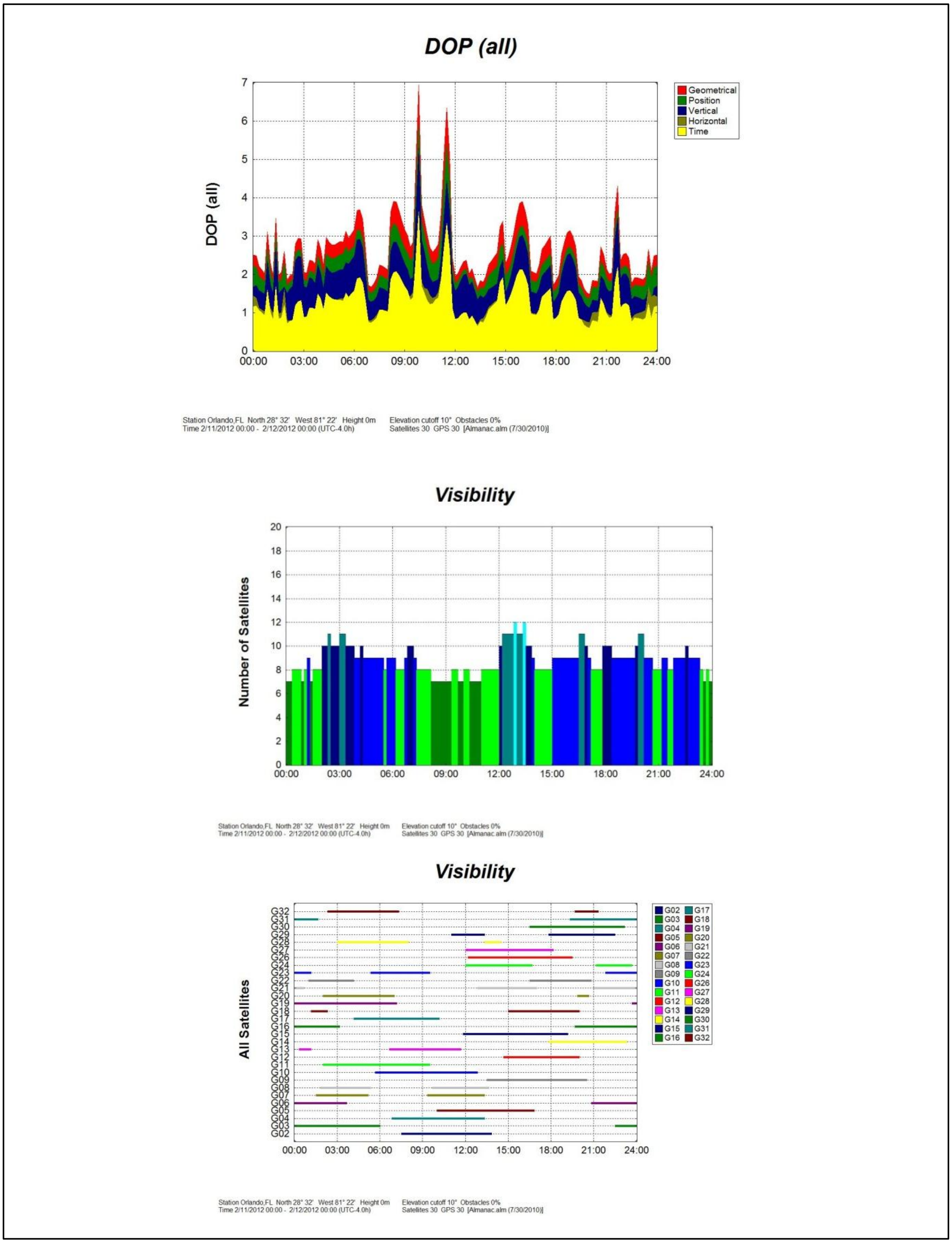
Planning for accuracy determination data collection for 50-second collection time on January 17, 2011



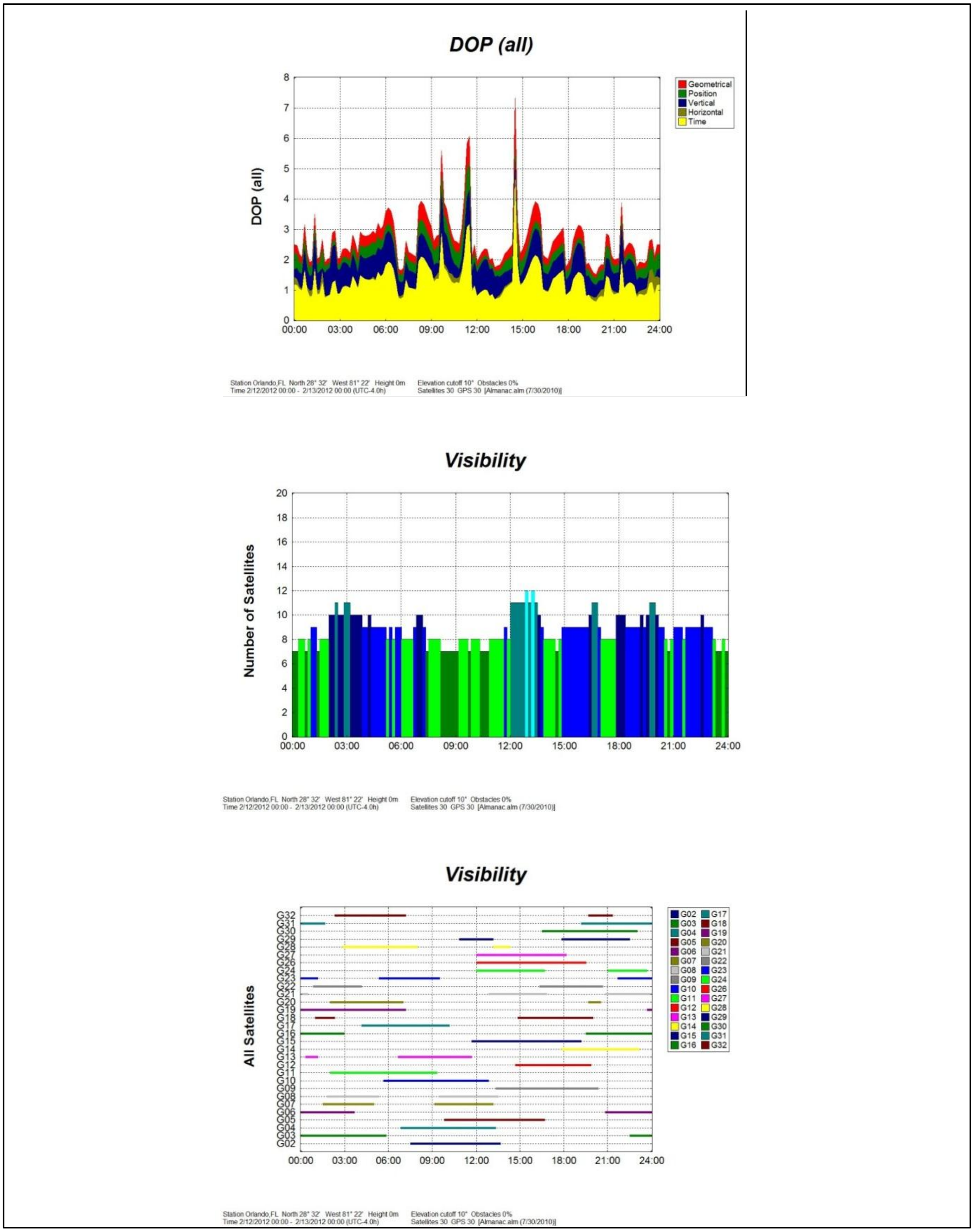
Planning for accuracy determination data collection for 100-second collection time on February 5, 2011



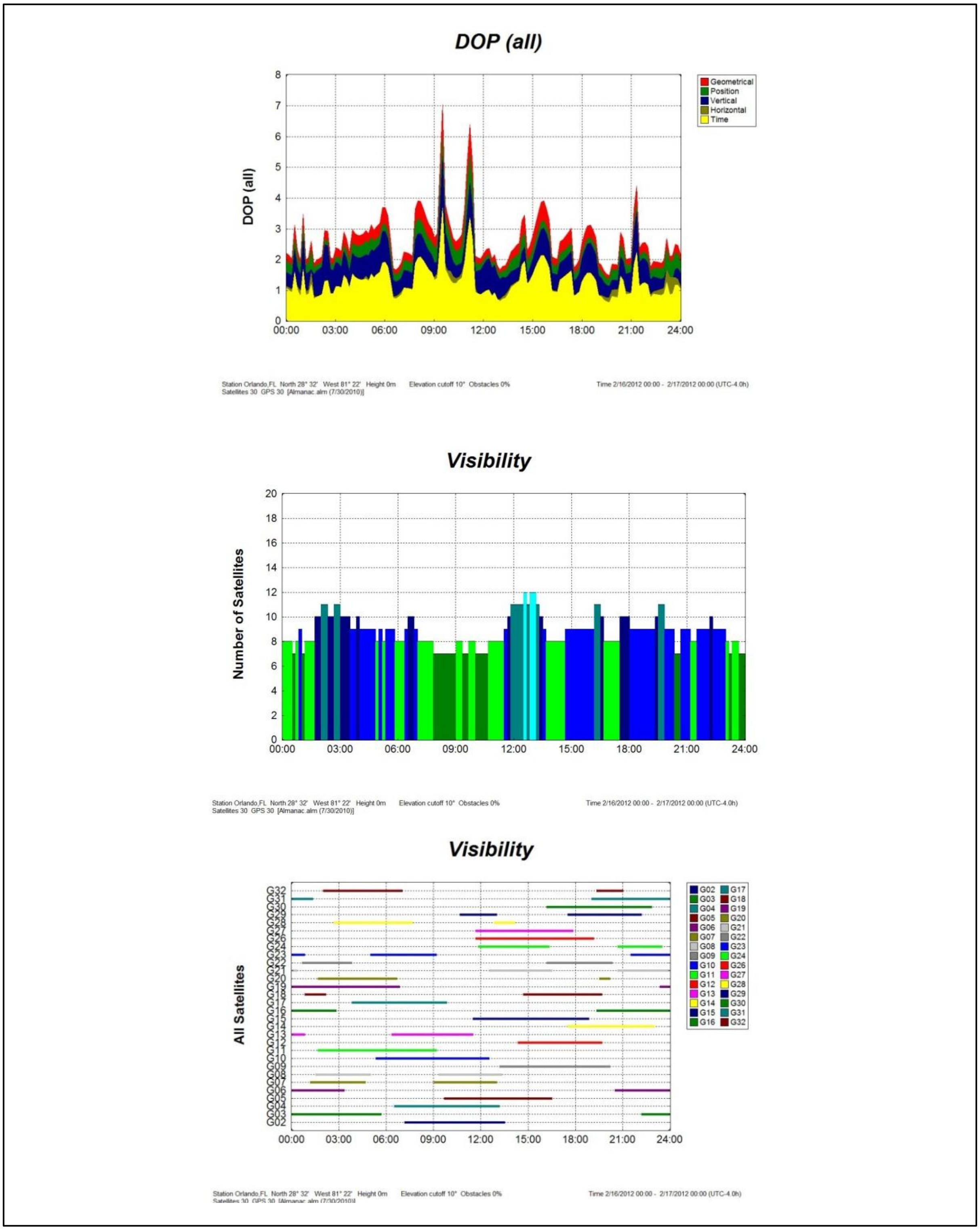
Planning for distance accuracy data collection on January 24, 2012



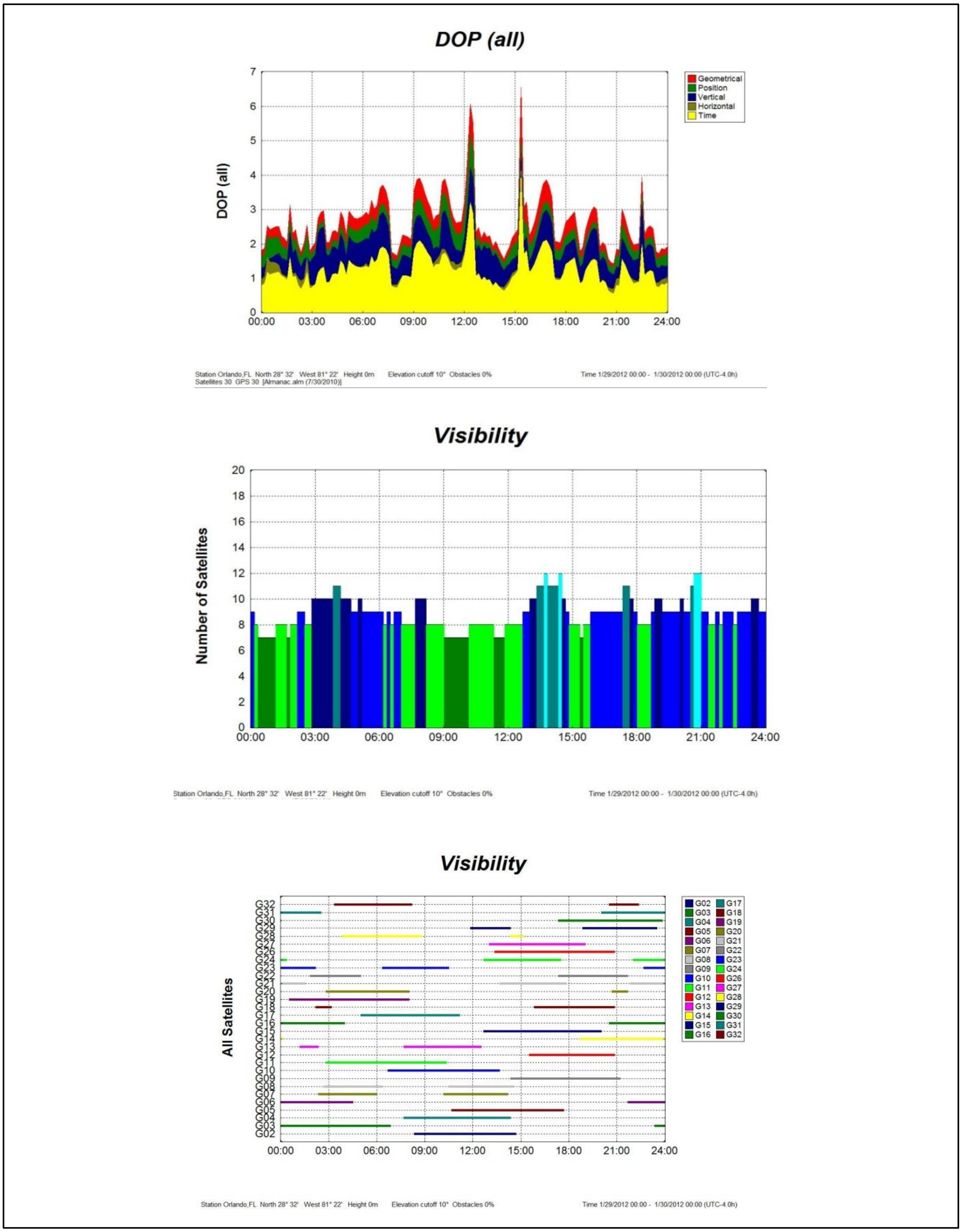
Planning for Scenario 1A data collection on February 11, 2012



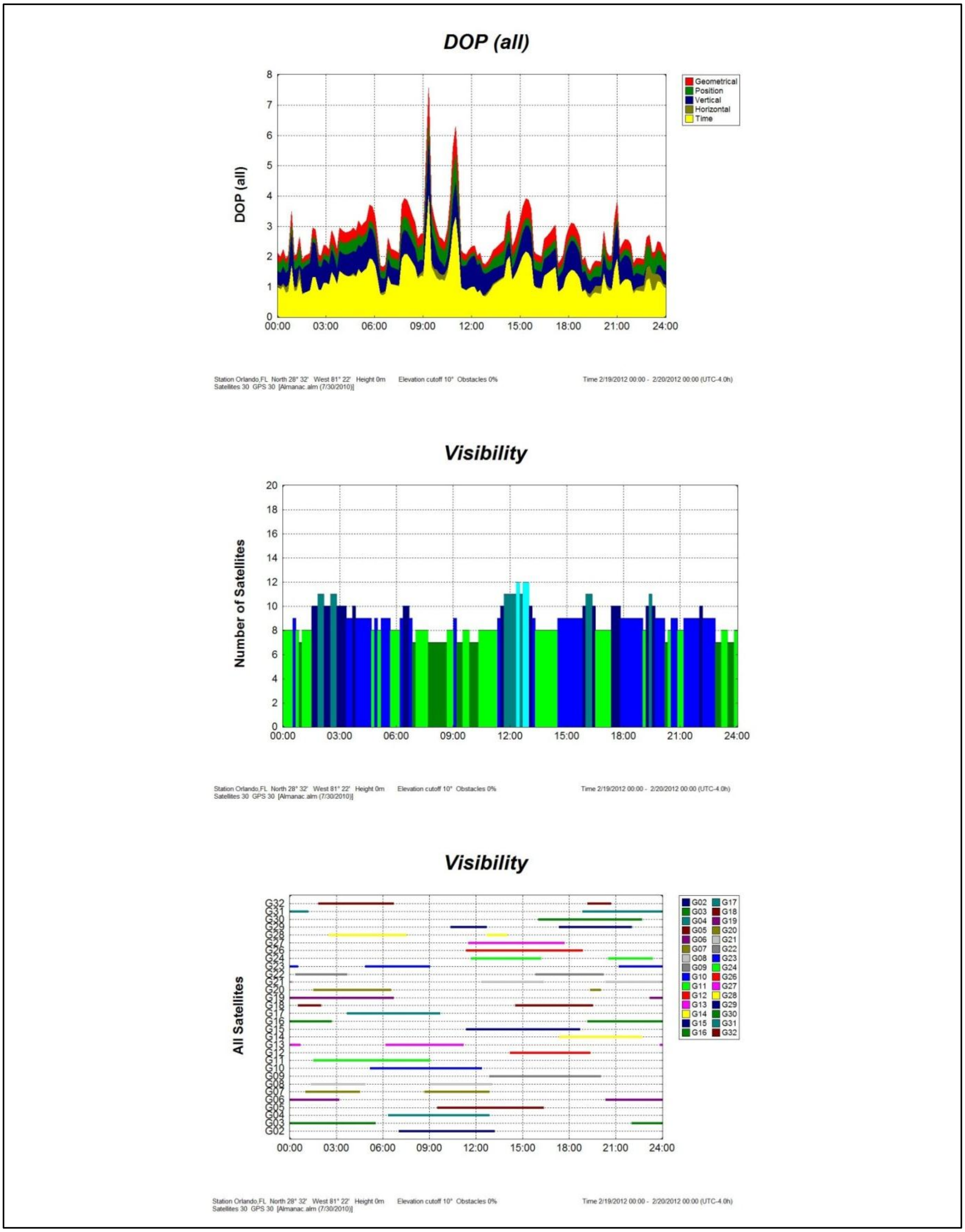
Planning for Scenario 1B data collection on February 12, 2012



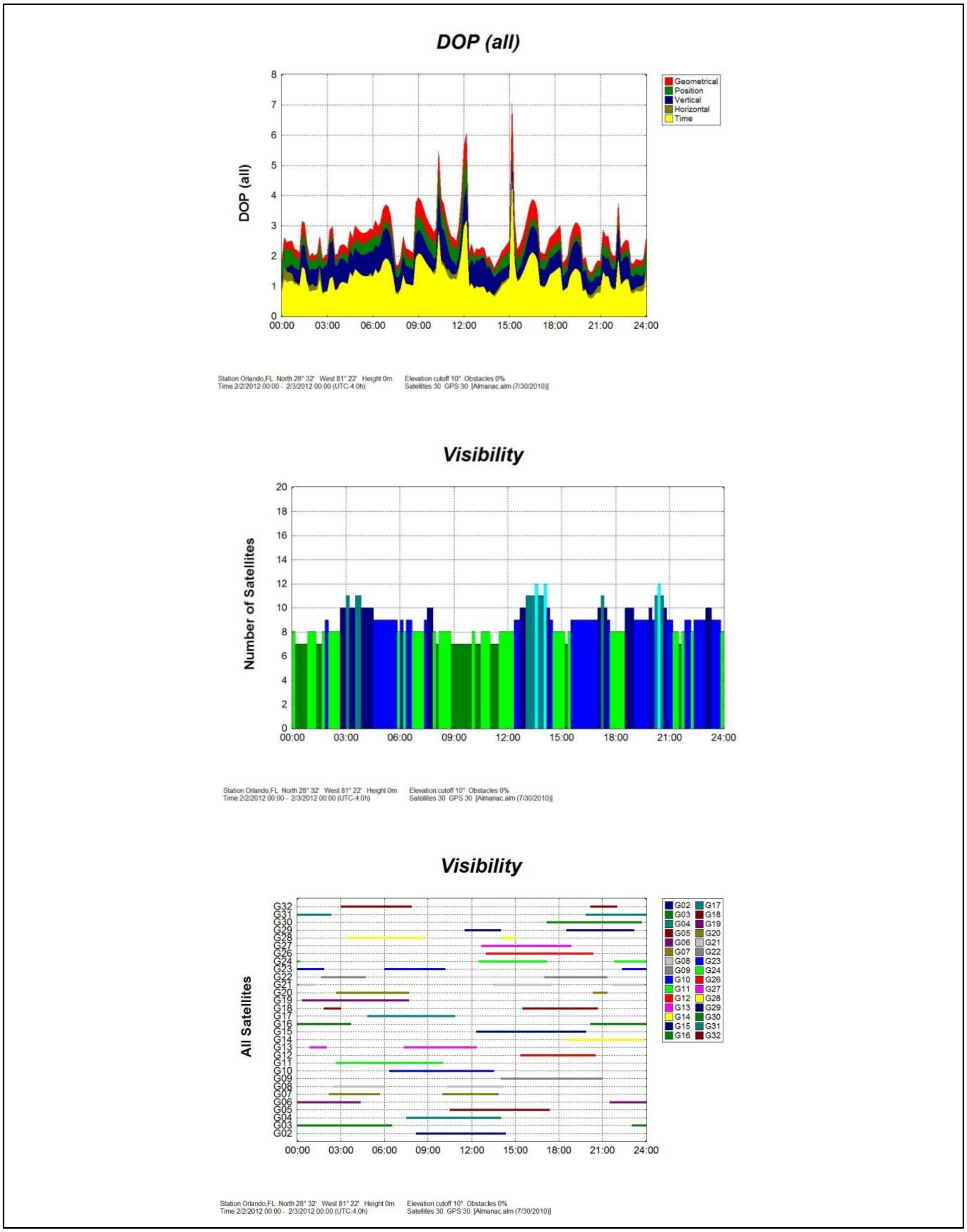
Planning for Scenario 2 data collection on February 16, 2012



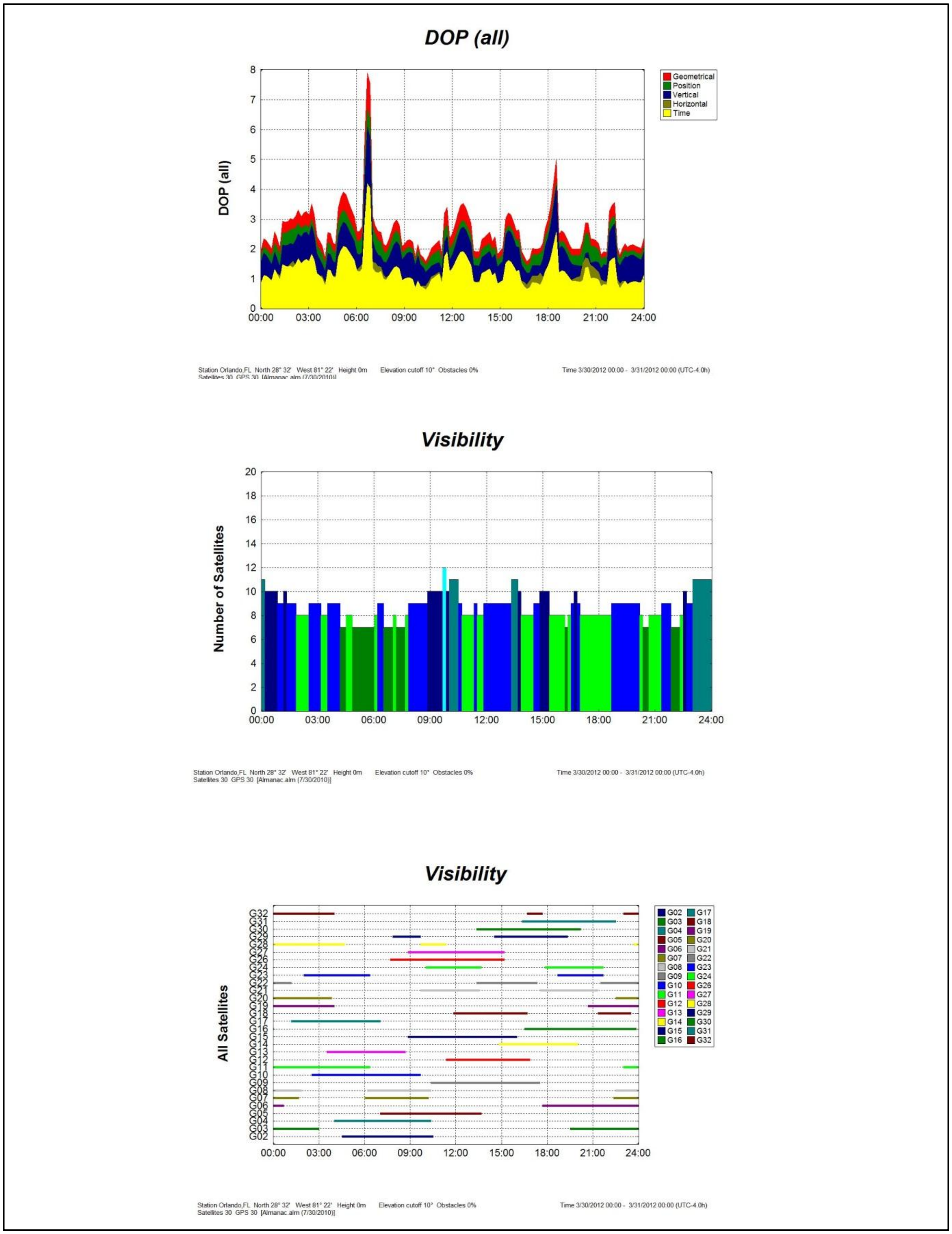
Planning for Scenario 3 data collection on January 29, 2012



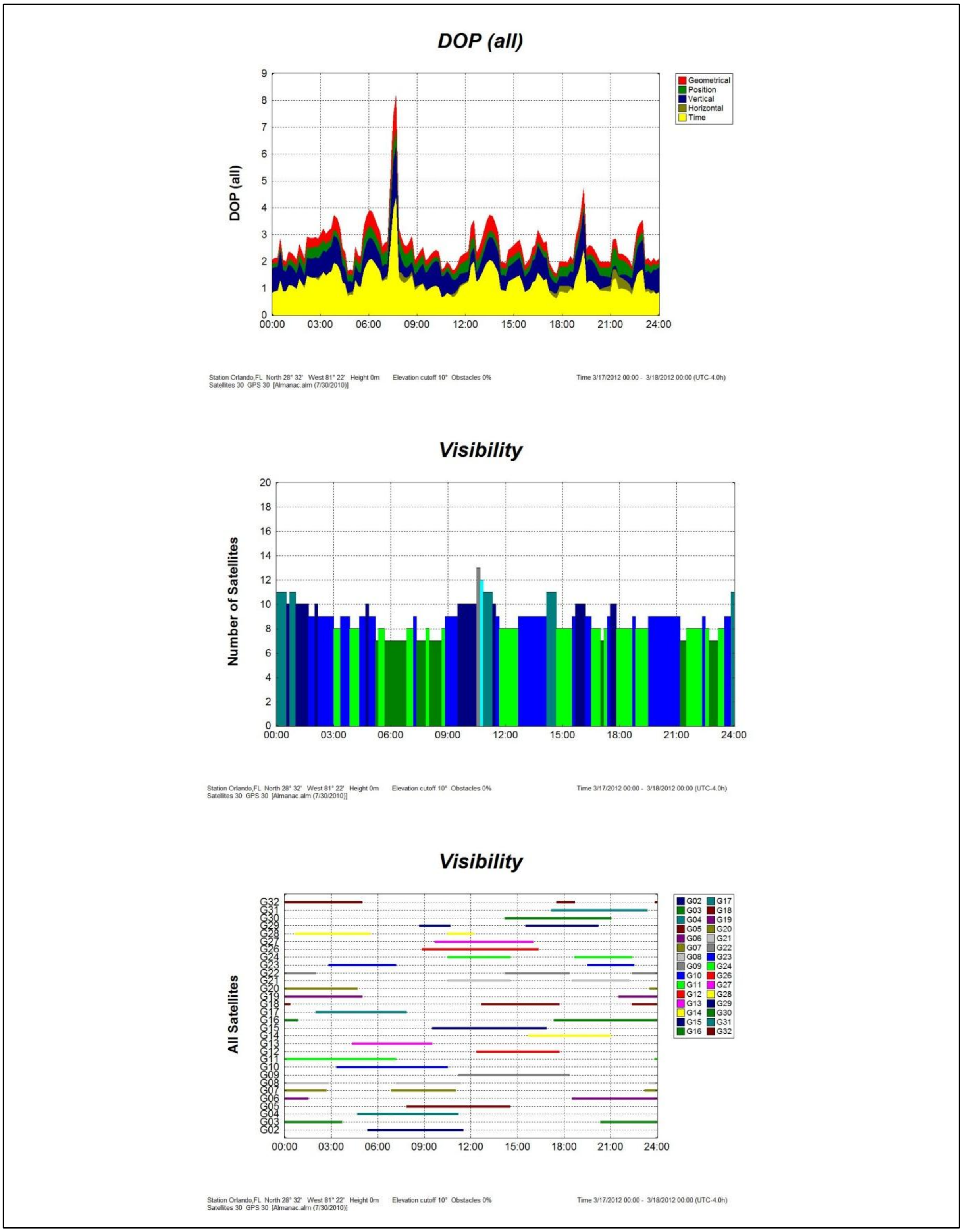
Planning for Scenario 4 data collection on February 20, 2012



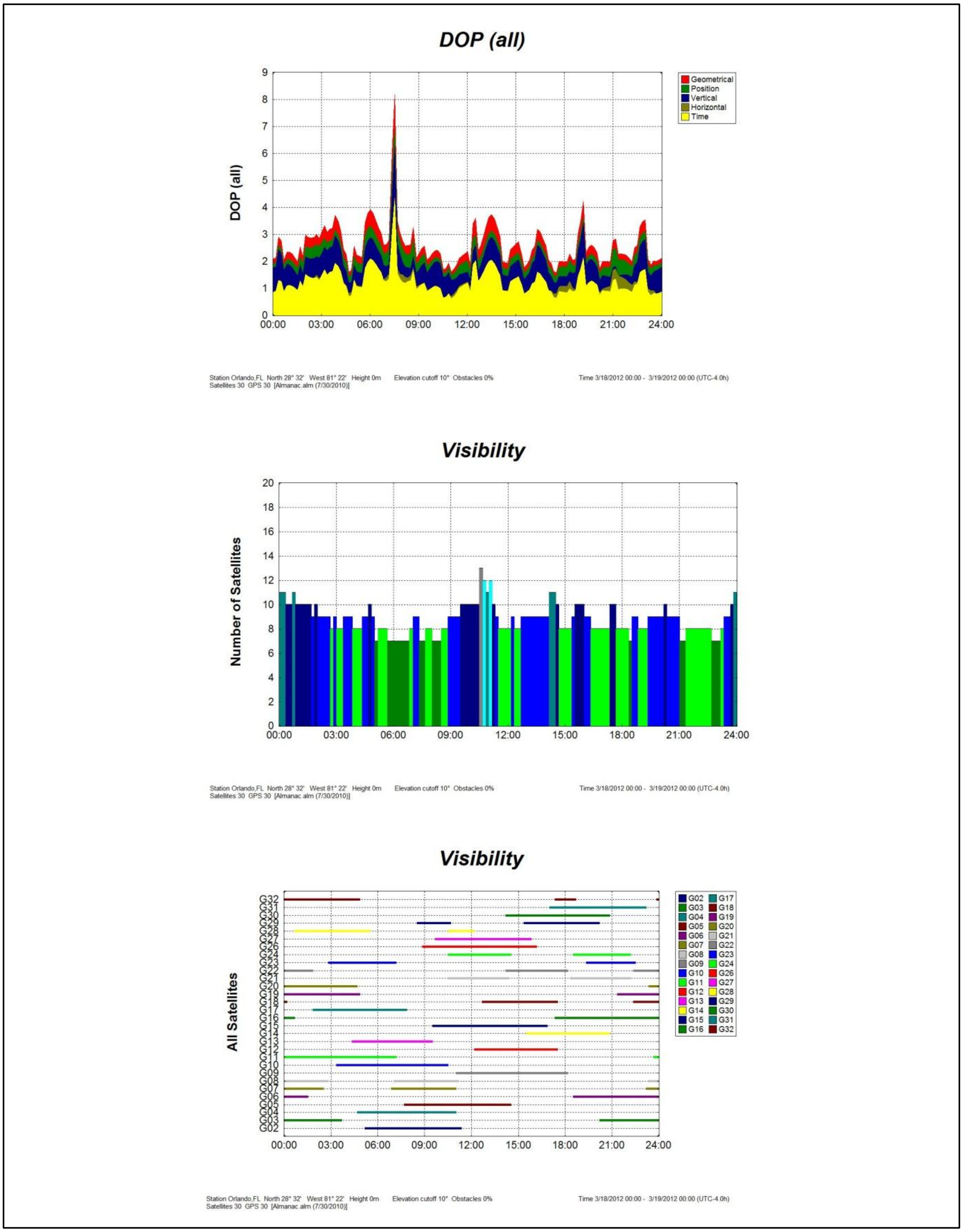
Planning for Scenario 5 data collection on February 2, 2012



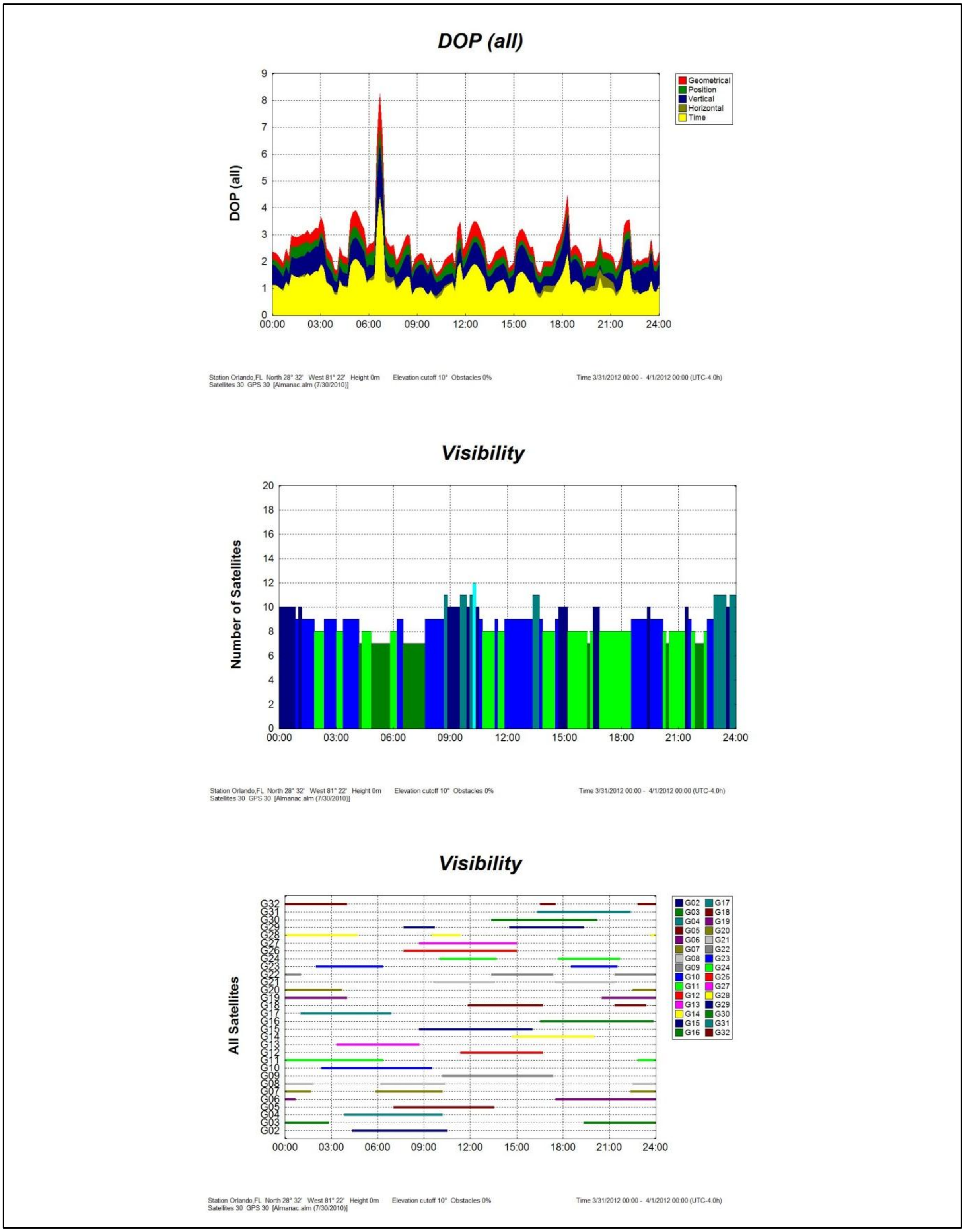
Planning for Scenario 6 data collection on March 31, 2012



Planning for Scenario 7 data collection on March 17, 2012



Planning for Scenario 8 data collection on March 18, 2012



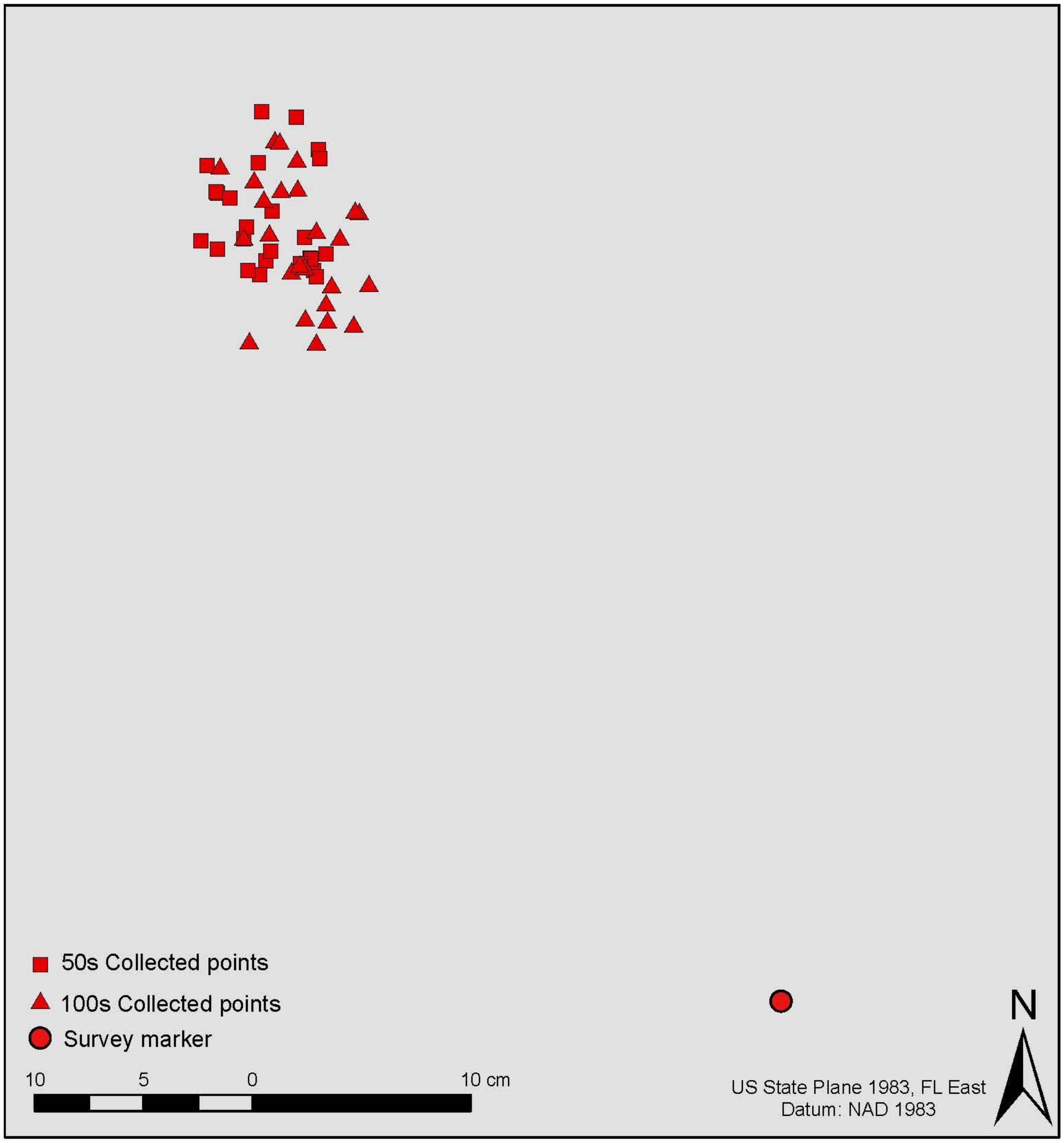
Planning for Scenario 9 data collection on March 31, 2012

APPENDIX C: ACCURACY MAPS

Collected Points and Survey Marker

VOLV119

Tree-Covered Area



100s Collection date: 2/5/12
100s Collection time: 13:32 - 16:44

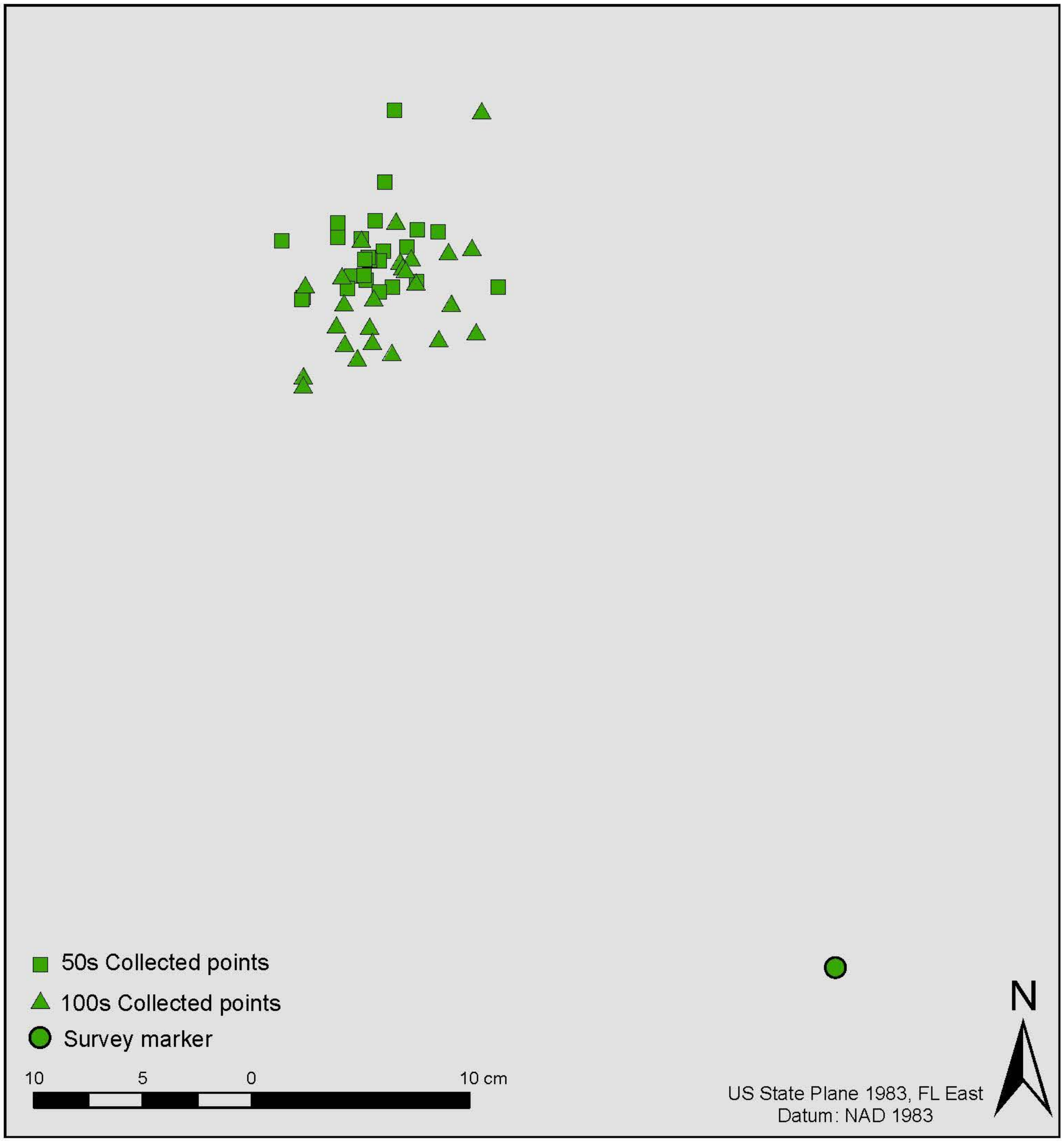
50s Collection date: 1/16/12
50s Collection time: 13:24 - 15:50

Collection time	Mean (cm)	Standard deviation (cm)	Range (cm)	95% Confidence Interval (cm)
50-second	42.97	2.27	39.57 to 46.32	42.08 to 43.86
100-second	41.34	2.87	37.08 to 46.24	40.22 to 42.47

Collected Points and Survey Marker

90501006

Area Near Structure



100s Collection date: 2/5/12
100s Collection time: 13:32 - 16:44

50s Collection date: 1/16/12
50s Collection time: 13:24 - 15:50

Collection time	Mean (cm)	Standard deviation (cm)	Range (cm)	95% Confidence Interval (cm)
50-second	39.20	1.80	34.91 to 42.00	38.50 to 39.91
100-second	37.3	1.95	34.85 to 42.62	36.54 to 38.06

Collected Points and Survey Marker

90501007

Open area

100s Collection date: 2/5/12
100s Collection time: 13:32 - 16:44

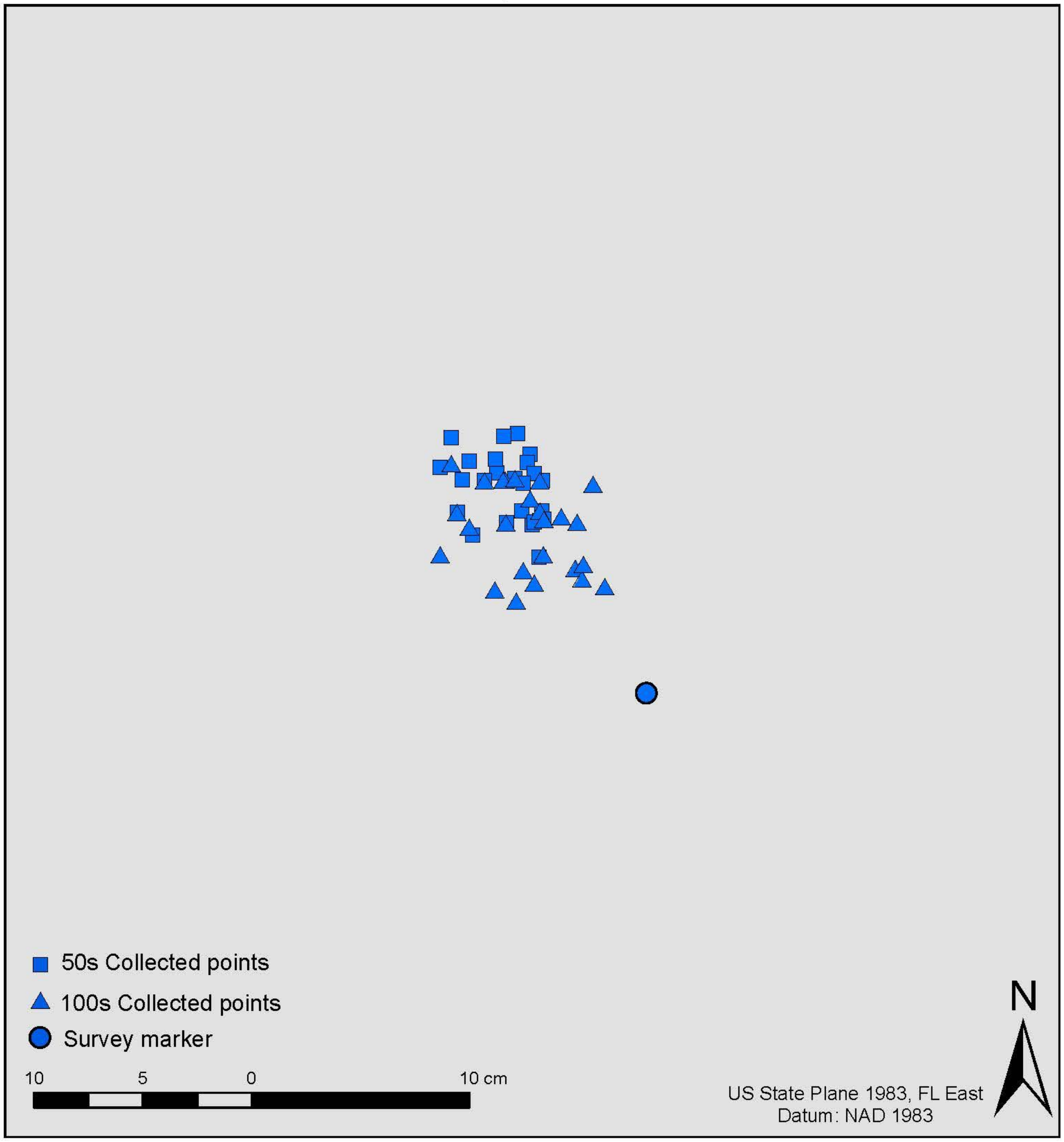
50s Collection date: 1/16/12
50s Collection time: 13:24 - 15:50

Collection time	Mean (cm)	Standard deviation (cm)	Range (cm)	95% Confidence Interval (cm)
50-second	11.55	1.65	9.13 to 13.38	10.89 to 12.21
100-second	9.59	1.82	7.36 to 12.84	8.86 to 10.32

Collected Points and Survey Marker

90501004

Open Area



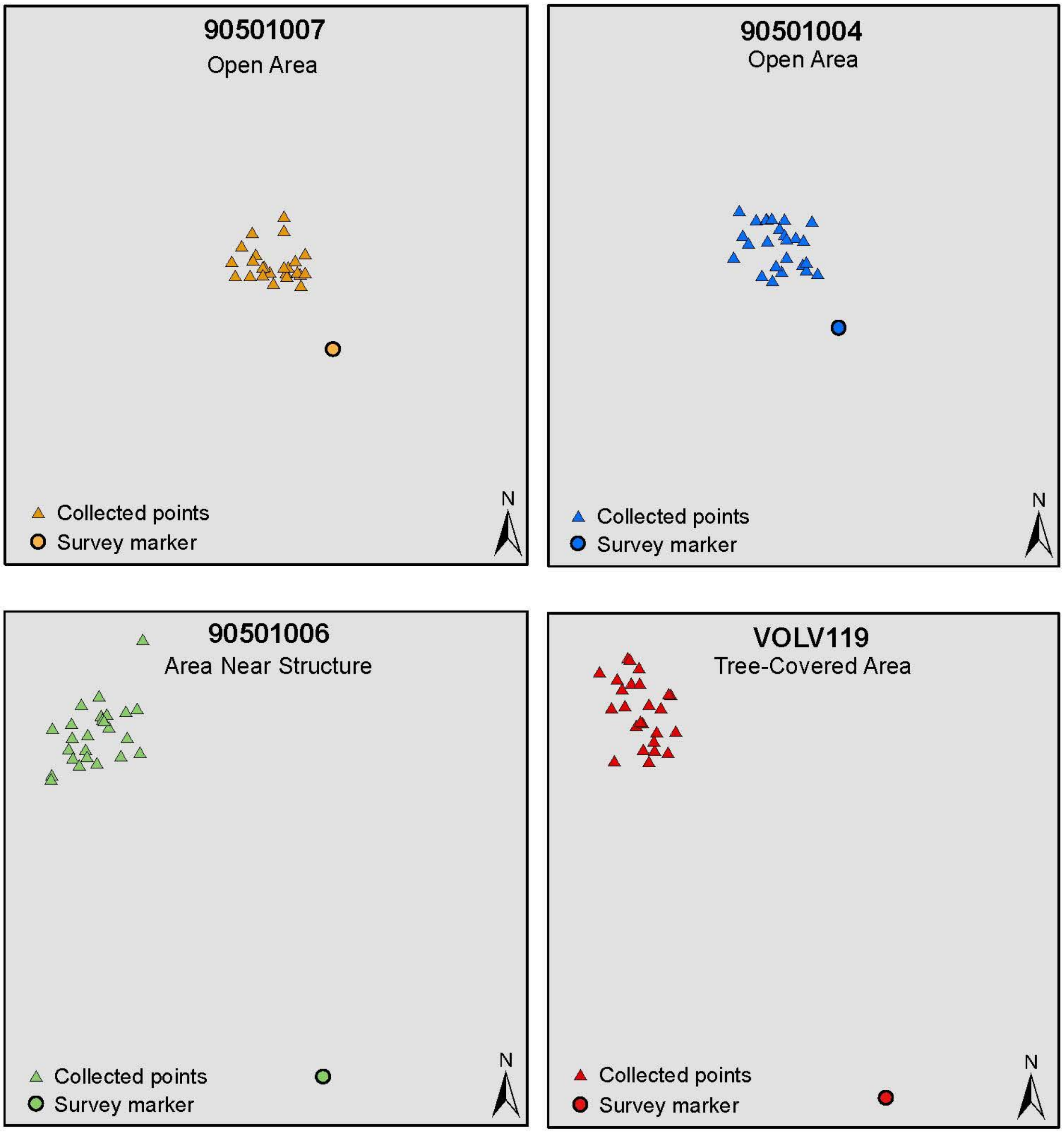
100s Collection date: 2/5/12
100s Collection time: 13:32 - 16:44

50s Collection date: 1/16/12
50s Collection time: 13:24 - 15:50

Collection time	Mean (cm)	Standard deviation (cm)	Range (cm)	95% Confidence Interval (cm)
50-second	11.48	1.75	7.98 to 14.79	10.80 to 12.16
100-second	9.51	2.25	5.30 to 13.87	8.63 to 10.39

Collected Points and Survey Markers

100-Second Collection Time



Survey marker	Environment	Mean (cm)	Standard deviation (cm)	Range (cm)	95% confidence interval (cm)
VOLV119	Tree cover	41.34	2.87	37.08 to 46.24	40.22 to 42.47
90501006	Structure	37.3	1.95	34.85 to 42.62	36.54 to 38.06
90501007	Open	9.59	1.82	7.36 to 12.84	8.86 to 10.32
90501004	Open	9.51	2.25	5.30 to 13.87	8.63 to 10.39

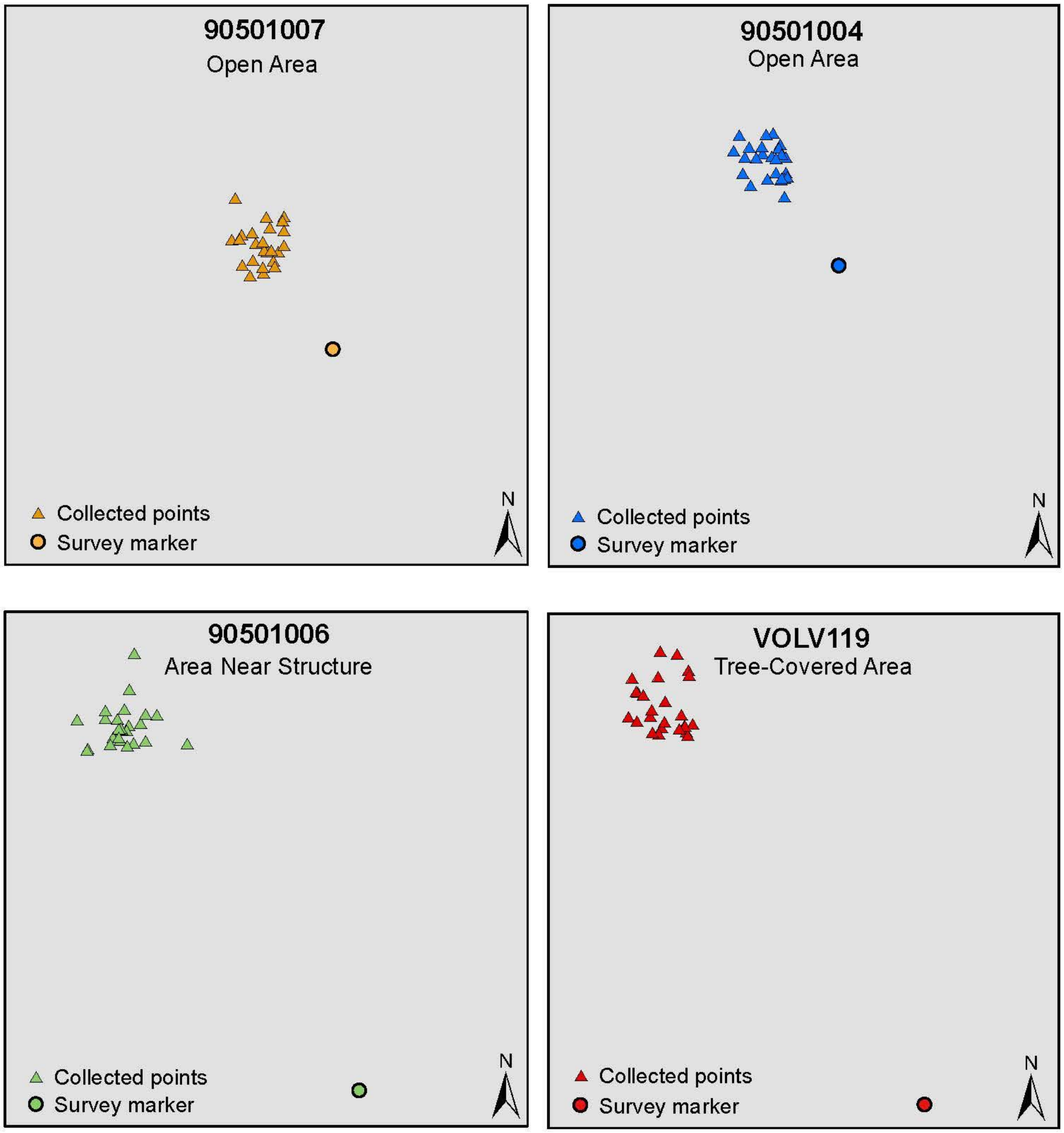
8 4 0 8 Centimeters

US State Plane 1983, FL East
Datum: NAD 1983

Collection date: 2/5/12
Collection time: 13:32 - 16:44

Collected Points and Survey Markers

50-Second Collection Time



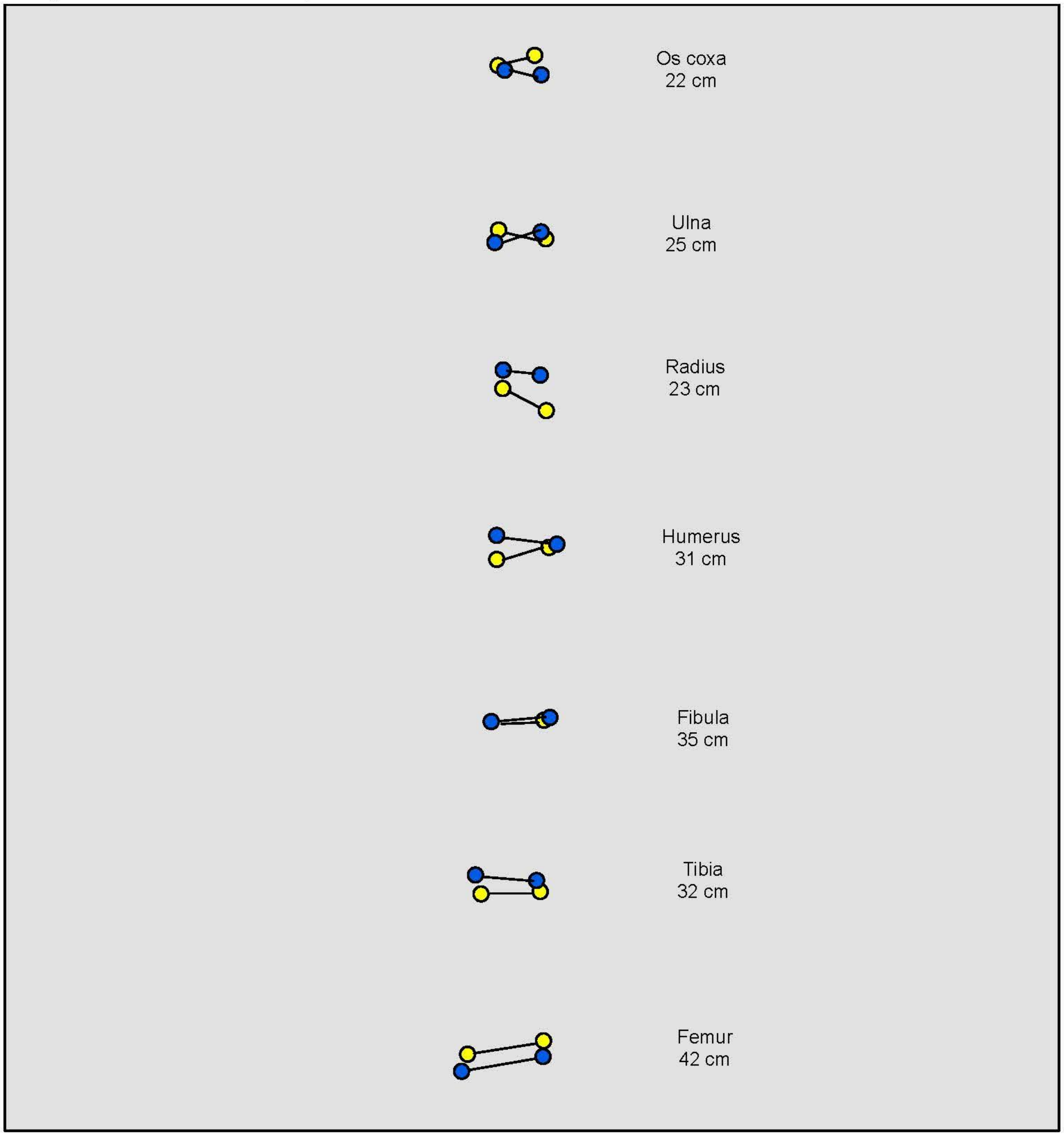
Survey marker	Environment	Mean (cm)	Standard deviation (cm)	Range (cm)	95% Confidence Interval (cm)
VOLV119	Tree cover	42.97	2.27	39.57 to 46.32	42.08 to 43.86
90501006	Structure	39.20	1.80	34.91 to 42.00	38.50 to 39.91
90501007	Open	11.55	1.65	9.13 to 13.38	10.89 to 12.21
90501004	Open	11.48	1.75	7.98 to 14.79	10.80 to 12.16

7 3.5 0 7 Centimeters

US State Plane 1983, FL East
Datum: NAD 1983

Collection date: 1/16/12
Collection time: 13:24 - 15:50

Long Bone Accuracy for 50-second and 100-second Time Collection



Legend

Collection Time

- 100 s (yellow)
- 50 s (blue)

	Actual max length (cm)	GIS max length (cm)		Difference (cm)	
		50 s	100 s	50 s	100 s
Humerus	31.0	35.5	31.8	4.5	0.8
Radius	23.0	21.4	25.2	1.6	2.2
Ulna	25.0	28.5	27.8	3.5	2.8
Femur	42.0	47.5	44.4	5.5	2.4
Tibia	32.0	34.4	33.4	2.4	1.4
Fibula	35.0	37.1	34.3	2.1	0.7
Os coxa	22.0	21.5	22.1	0.5	0.1
		Average difference		**2.9**	**1.5**

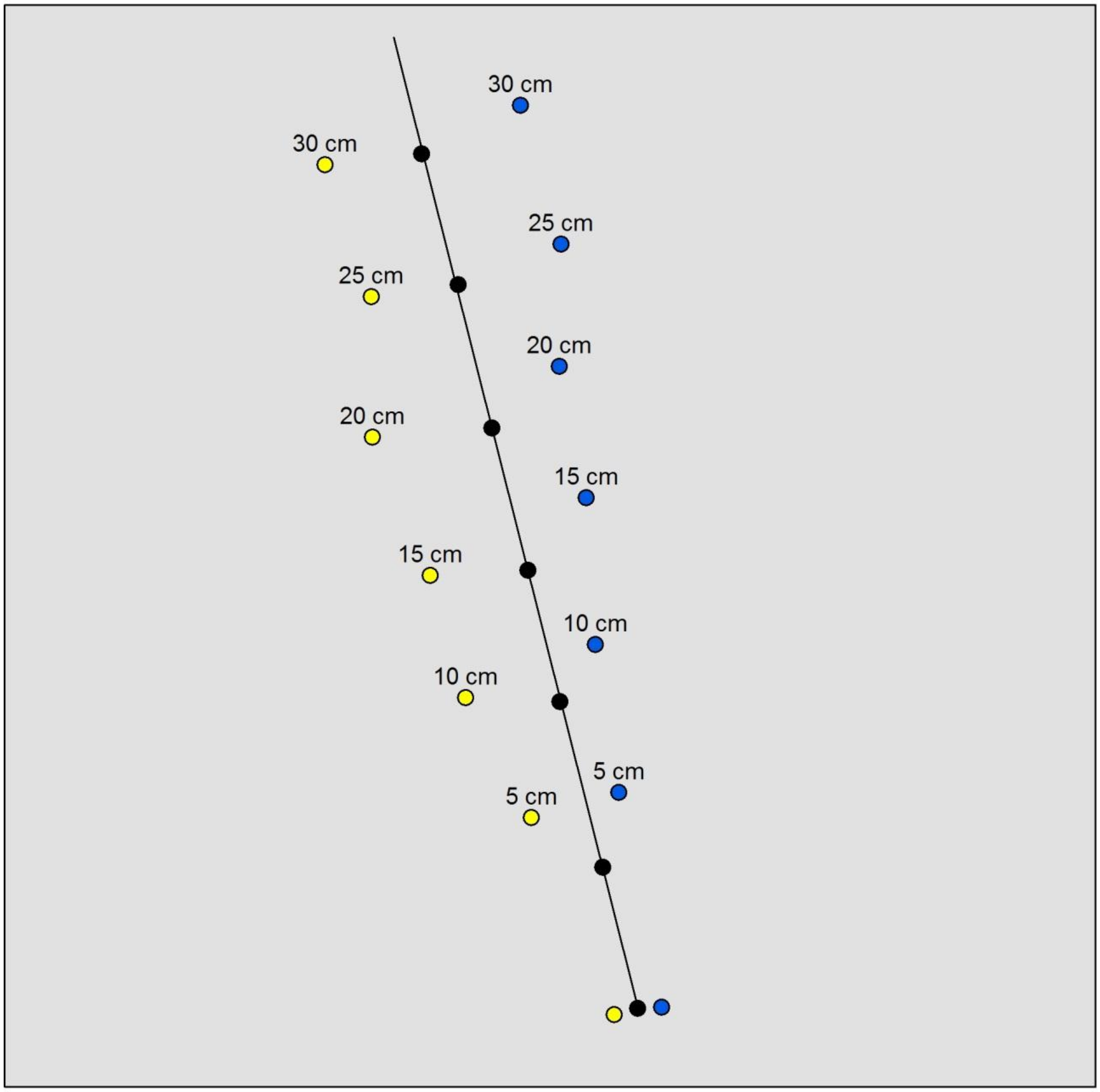
0 35 70 140 Centimeters

Collection date: 1/24/12
Collection time: 13:50-14:57
Obstructions: None

Coordinate System: UTM, Zone 17 N
Datum: WGS 1984

N

Distance Accuracy for 50-second and 100-second Time Collection



Legend

Collection Time

- 100 s
- 50 s

	GIS length (cm)		Difference (cm)	
	50 s	**100 s**	**50 s**	**100 s**
5 cm	7.5	7.3	2.5	2.3
10 cm	12.6	11.9	2.6	1.9
15 cm	17.6	16.2	2.6	1.2
20 cm	22.2	21.4	2.2	1.4
25 cm	26.4	25.9	1.4	0.9
30 cm	31.1	30.6	1.1	0.6

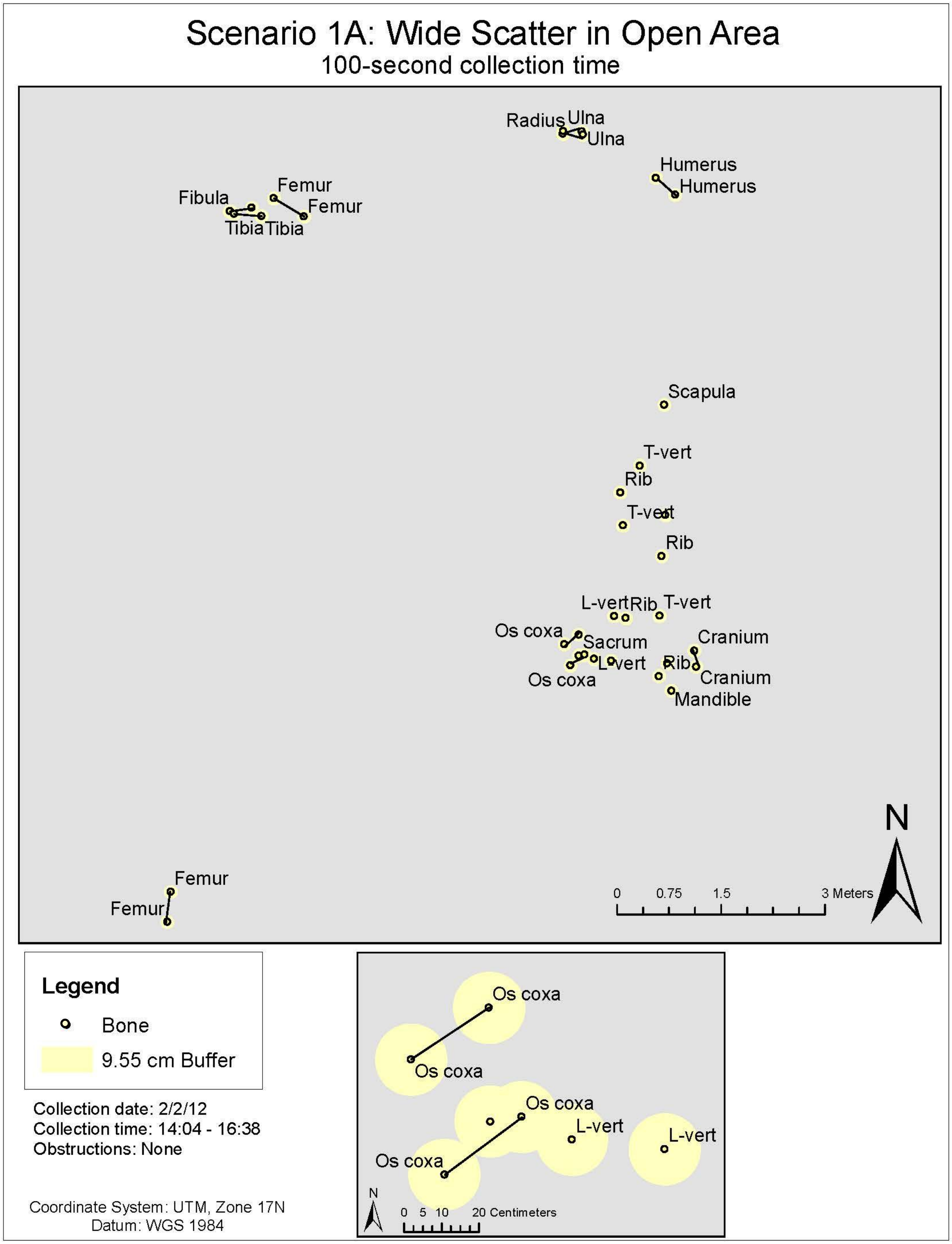
0 2 4 8 Centimeters

N

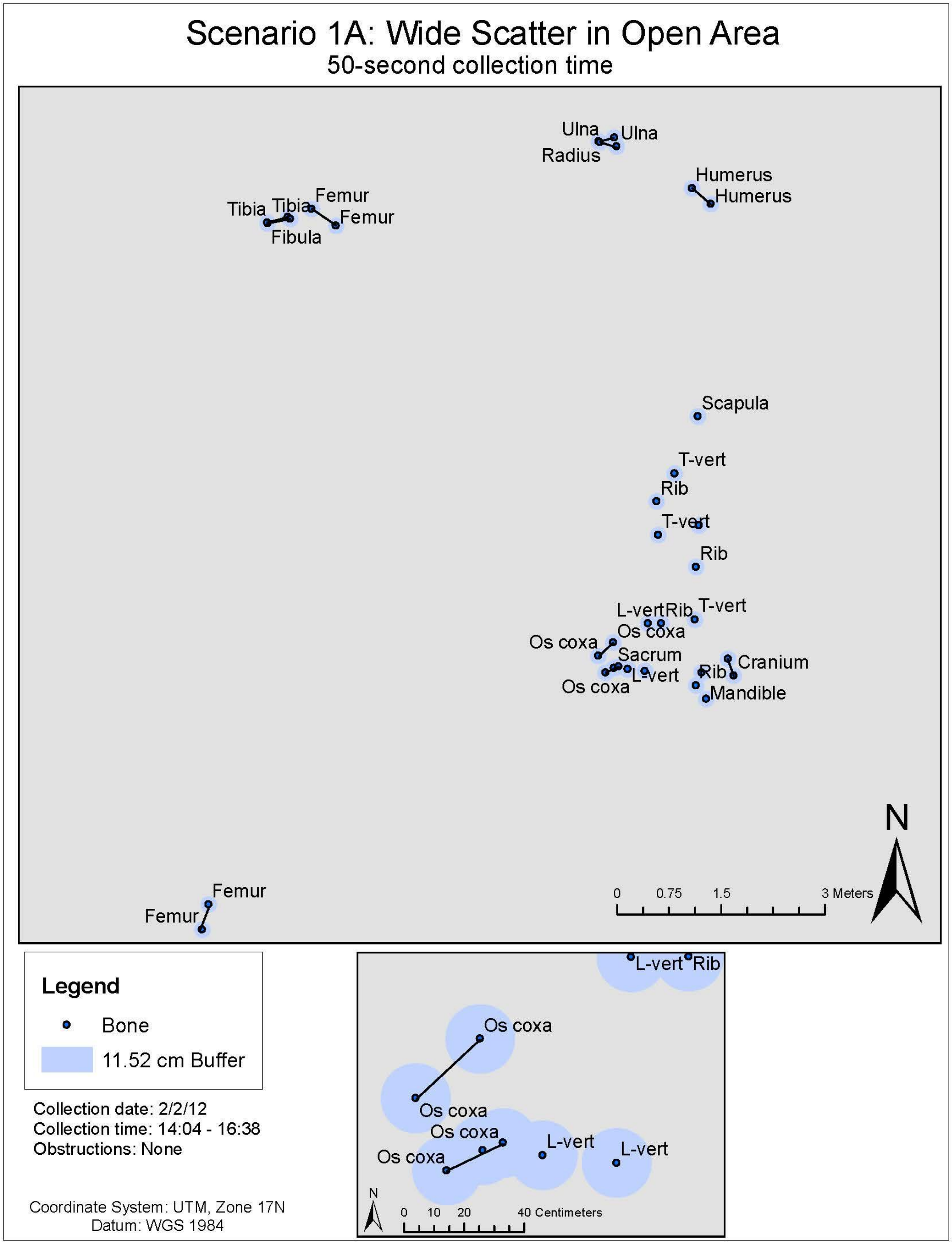
Collection date: 1/24/12
Collection time: 13:50 - 14:57
Obstructions: None

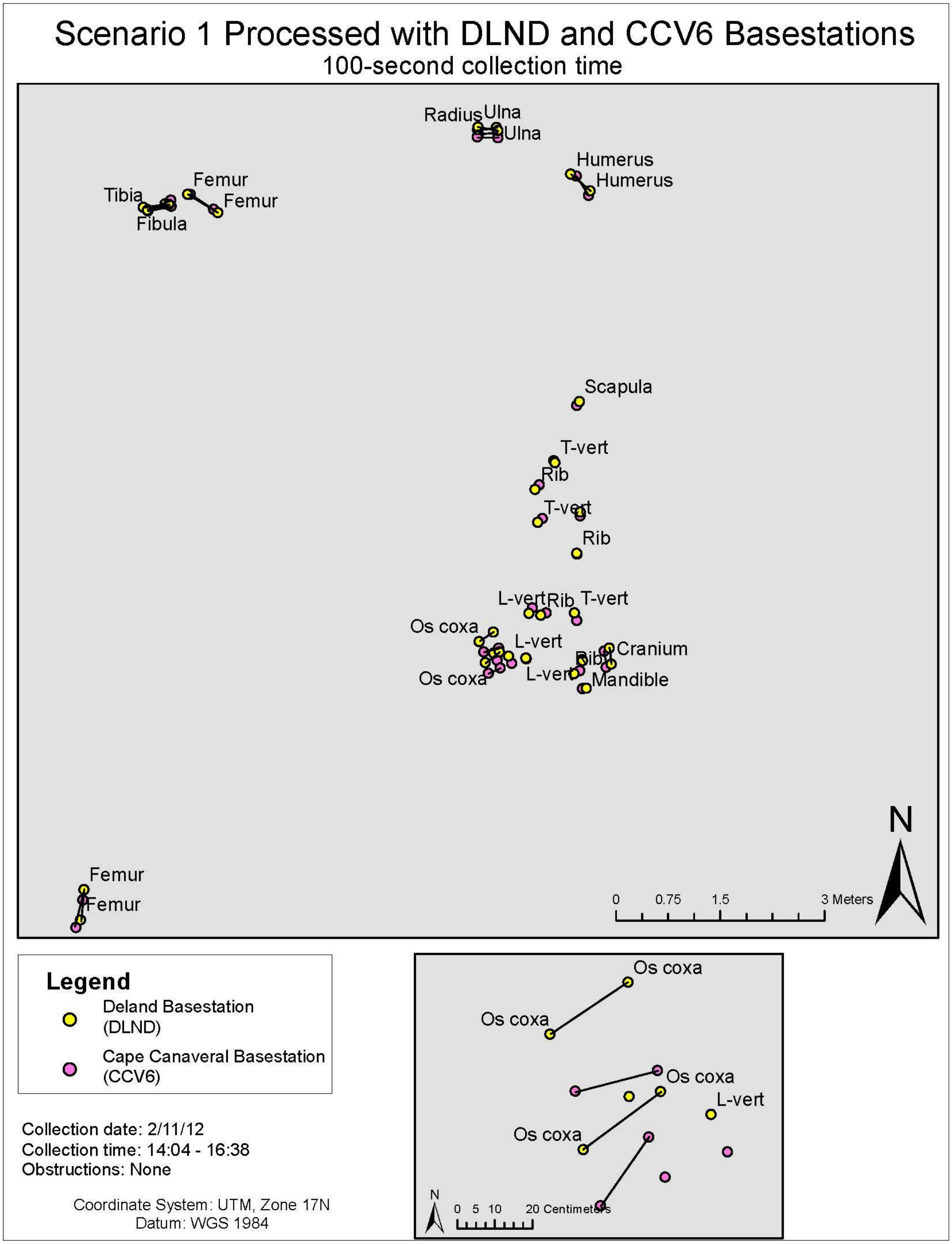
Coordinate System: UTM, Zone 17N
Datum: WGS1984

APPENDIX D: SCENARIO MAPS

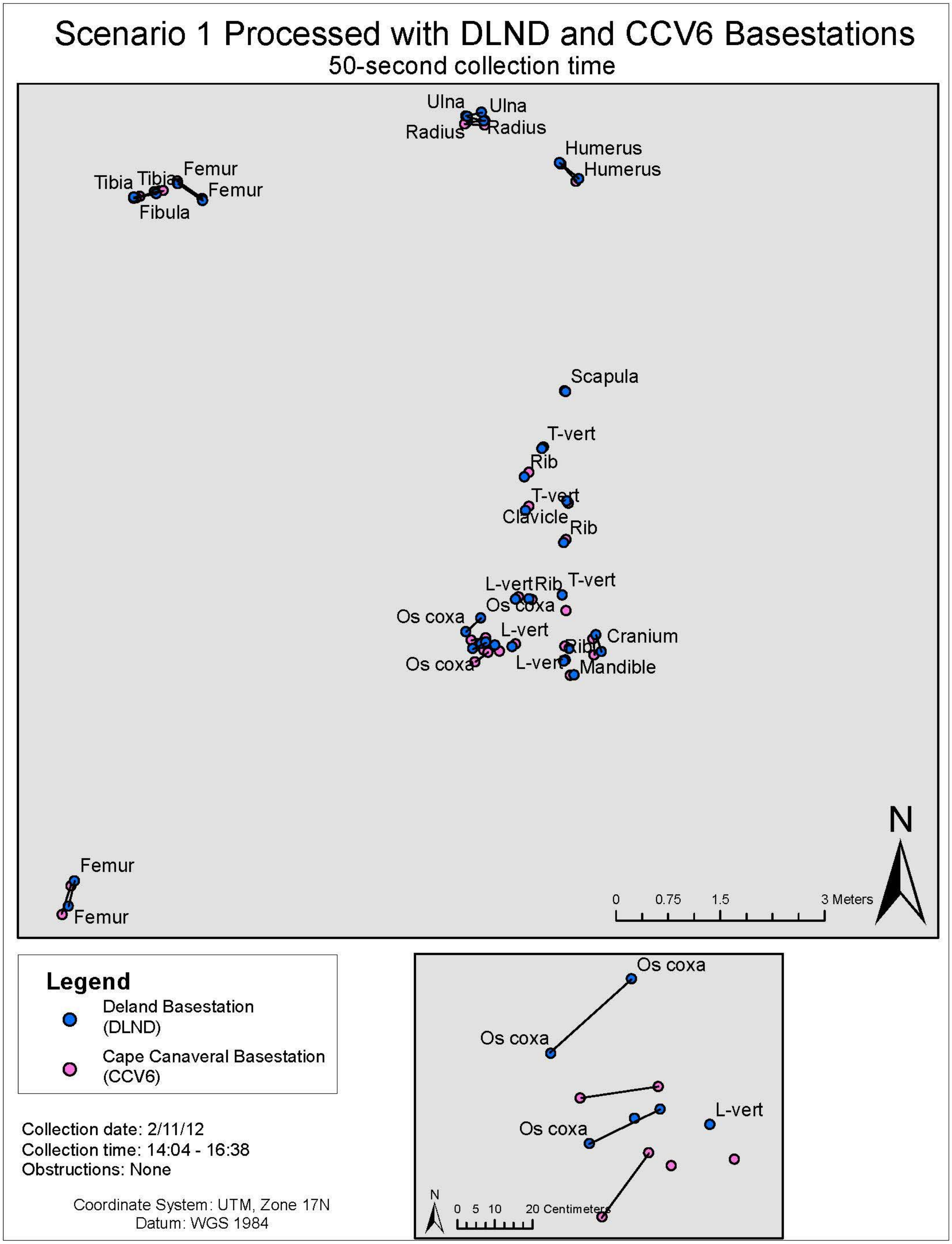


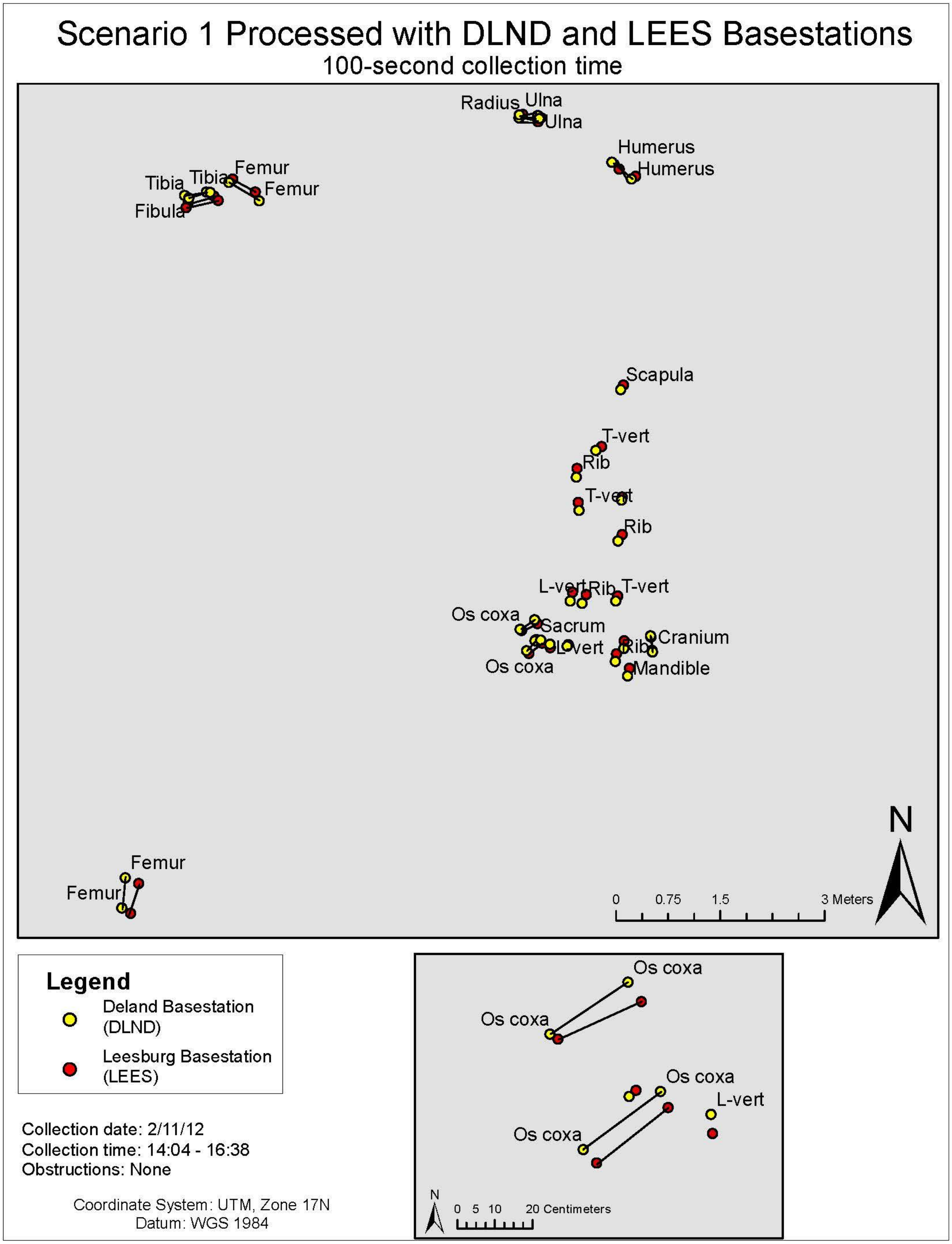
Scenario 1A: Wide Scatter in Open Area
100-second collection time
Radius
Ulna
Ulna
Humerus
Humerus
Fibula
Femur
Femur
Tibia
Tibia
Scapula
T-vert
Rib
T-vert
Rib
L-vert
Rib
T-vert
Os coxa
Sacrum
Cranium
L-vert
Rib
Os coxa
Cranium
Mandible
N
0
0.75
1.5
3 Meters
Femur
Femur
Legend
Bone
9.55 cm Buffer
Collection date: 2/2/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Os coxa
Os coxa
Os coxa
L-vert
L-vert
Os coxa
N
0 5 10
20 Centimeters

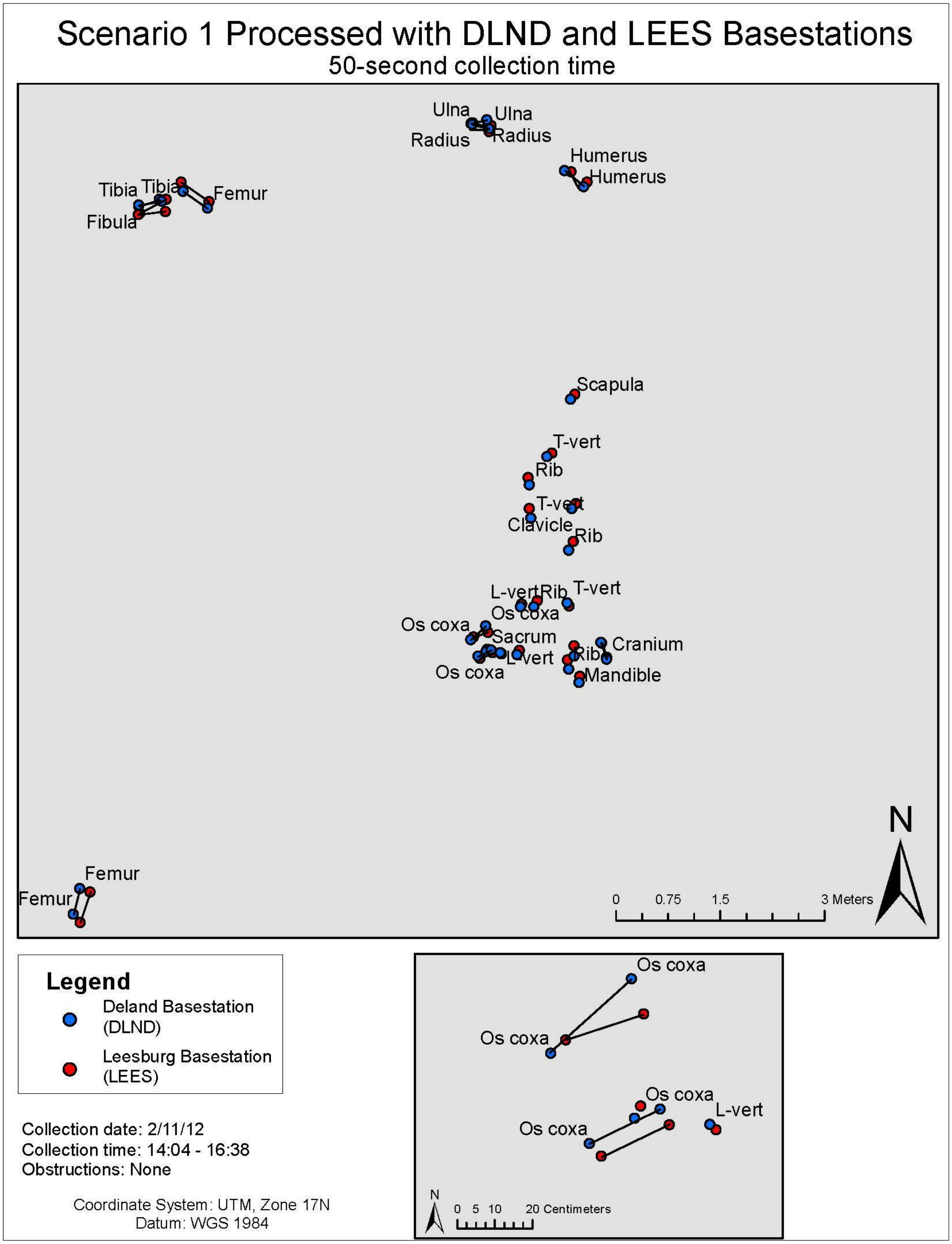

Scenario 1A: Wide Scatter in Open Area
50-second collection time
Ulna
Ulna
Radius
Humerus
Humerus
Tibia
Tibia
Femur
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Rib
L-vert
Rib
T-vert
Os coxa
Os coxa
Sacrum
Cranium
Rib
L-vert
Os coxa
Mandible
N
0
0.75
1.5
3 Meters
Femur
Femur
Legend
Bone
11.52 cm Buffer
Collection date: 2/2/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
L-vert
Rib
Os coxa
Os coxa
Os coxa
Os coxa
L-vert
L-vert
N
0 10 20
40 Centimeters

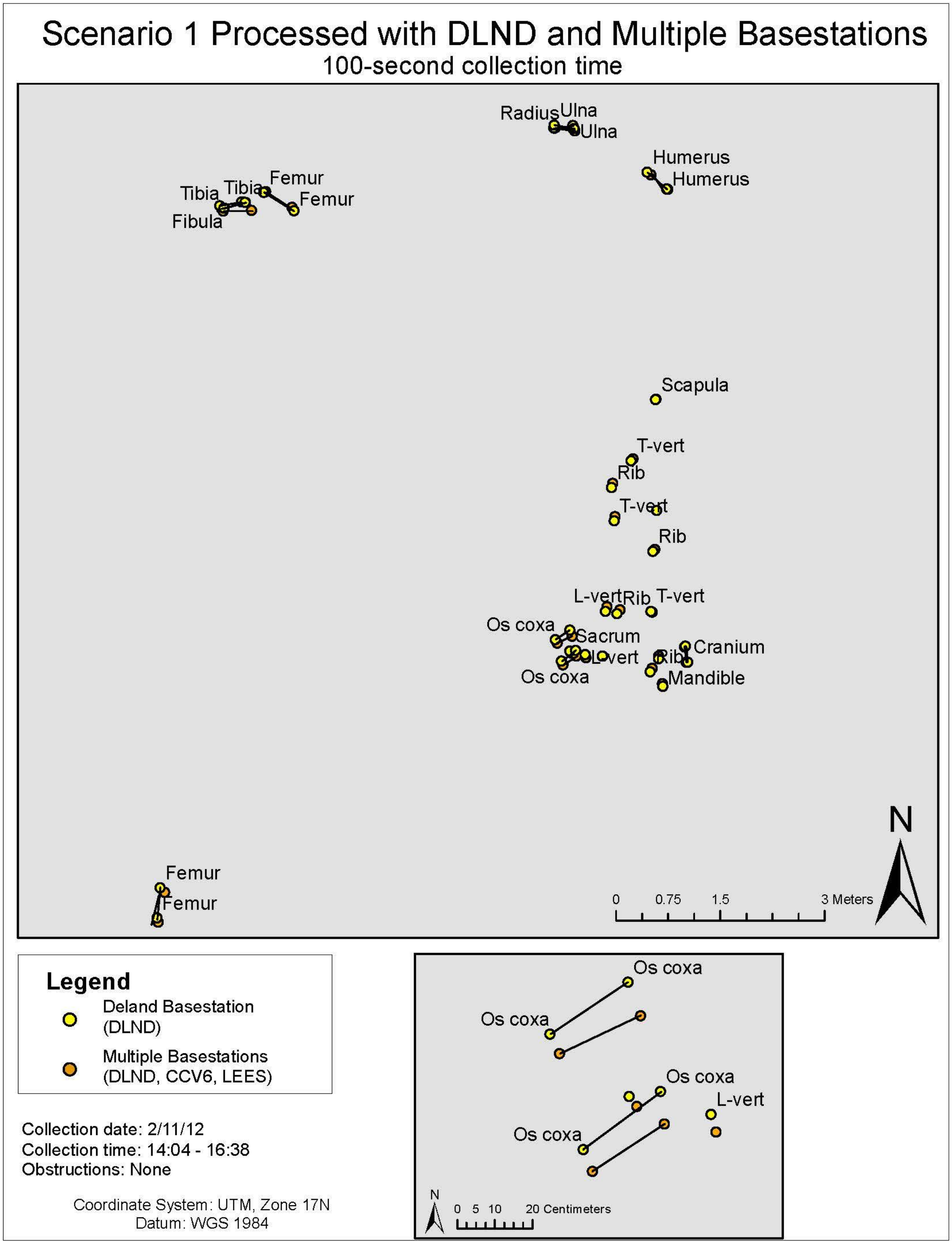


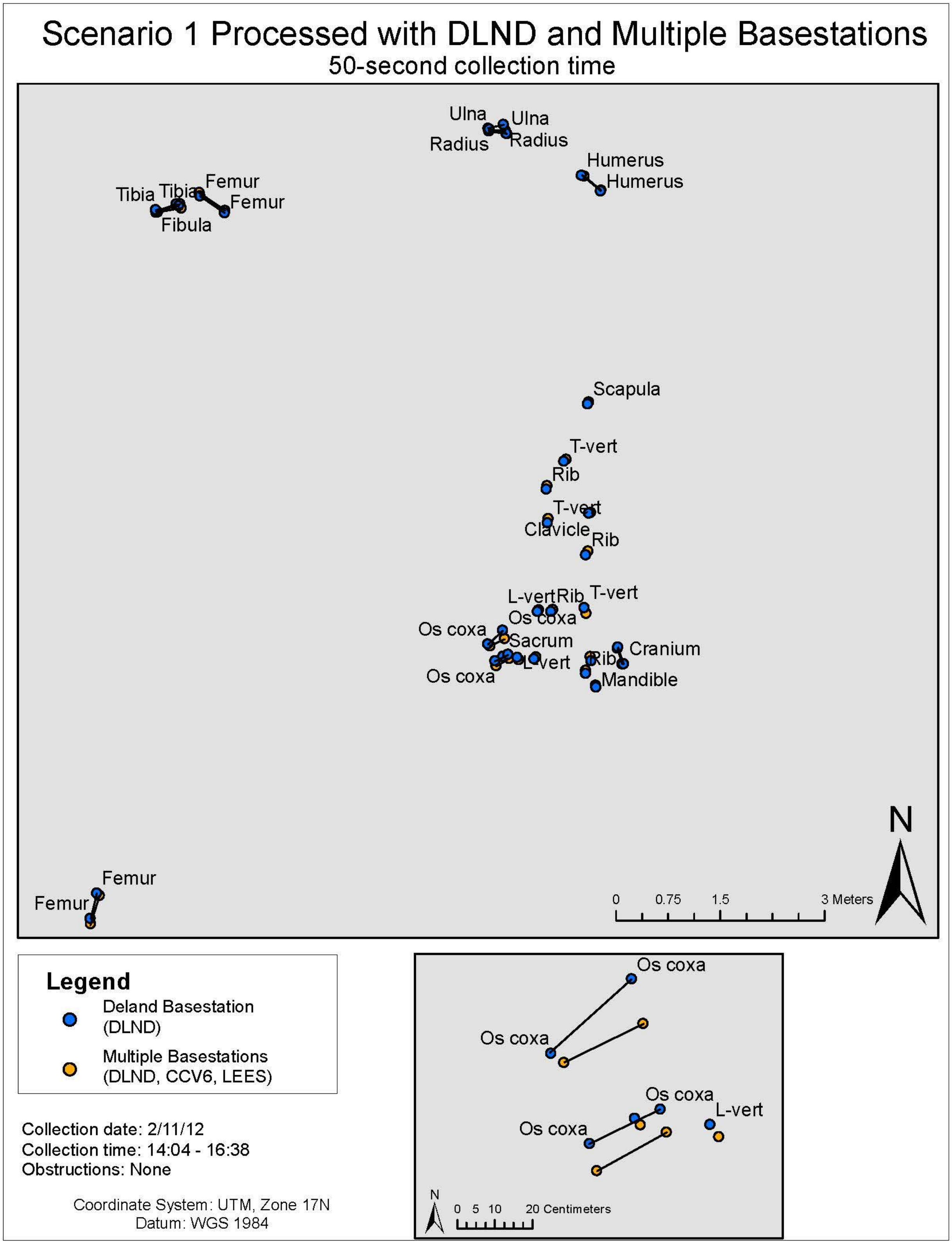
Scenario 1 Processed with DLND and CCV6 Basestations
100-second collection time
Radius
Ulna
Ulna
Humerus
Humerus
Femur
Tibia
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Rib
L-vert
Rib
T-vert
Os coxa
L-vert
Cranium
Rib
Os coxa
L-vert
Mandible
N
Femur
Femur
0
0.75
1.5
3 Meters
Legend
Deland Basestation (DLND)
Cape Canaveral Basestation (CCV6)
Os coxa
Os coxa
Os coxa
L-vert
Os coxa
N
0 5 10 20 Centimeters
Collection date: 2/11/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984


Scenario 1 Processed with DLND and CCV6 Basestations
50-second collection time
Ulna
Ulna
Radius
Radius
Humerus
Humerus
Tibia
Tibia
Femur
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Clavicle
Rib
L-vert
Rib
T-vert
Os coxa
Os coxa
L-vert
Cranium
Rib
Os coxa
L-vert
Mandible
Femur
Femur
N
0
0.75
1.5
3 Meters
Legend
Deland Basestation (DLND)
Cape Canaveral Basestation (CCV6)
Collection date: 2/11/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Os coxa
Os coxa
Os coxa
L-vert
N
0 5 10 20 Centimeters

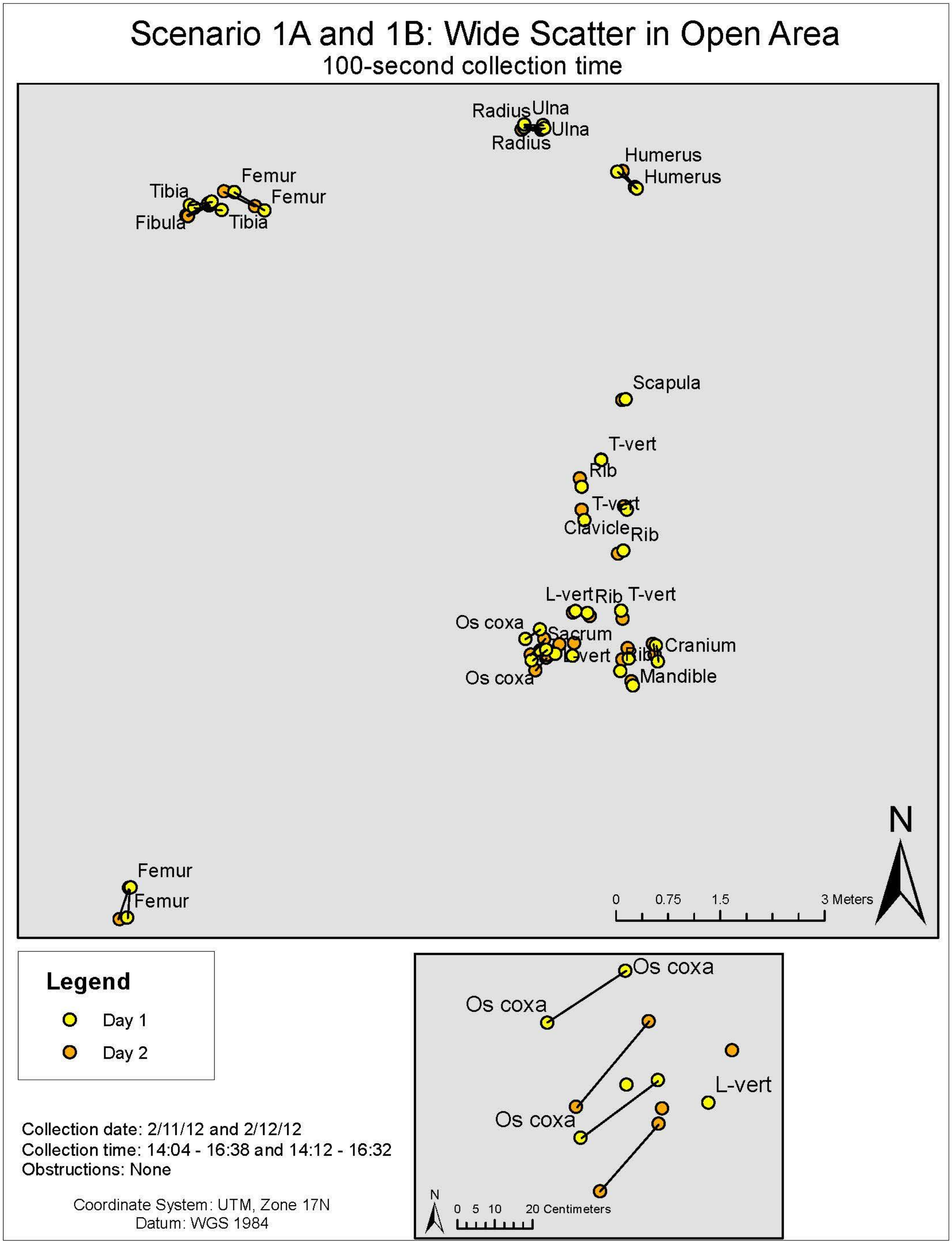

Scenario 1 Processed with DLND and LEES Basestations
100-second collection time
Radius
Ulna
Ulna
Humerus
Humerus
Tibia
Tibia
Femur
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Rib
L-vert
Rib
T-vert
Os coxa
Sacrum
L-vert
Rib
Cranium
Os coxa
Mandible
Femur
Femur
N
0
0.75
1.5
3 Meters
Legend
Deland Basestation (DLND)
Leesburg Basestation (LEES)
Collection date: 2/11/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Os coxa
Os coxa
Os coxa
L-vert
Os coxa
N
0 5 10 20 Centimeters

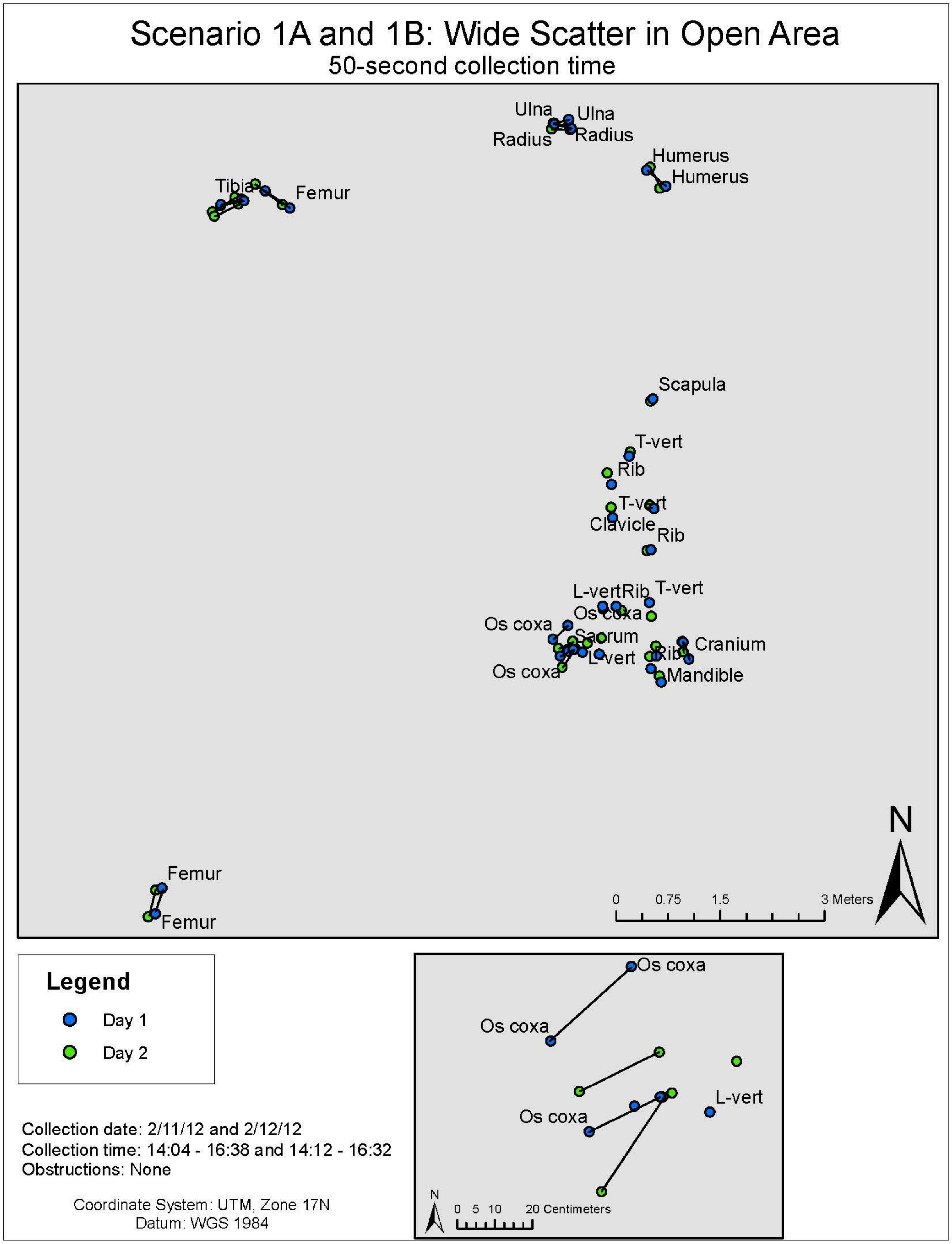

Scenario 1 Processed with DLND and LEES Basestations
50-second collection time
Ulna
Ulna
Radius
Radius
Humerus
Humerus
Tibia
Tibia
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Clavicle
Rib
L-vert
Rib
T-vert
Os coxa
Os coxa
Sacrum
Cranium
L-vert
Rib
Os coxa
Mandible
Femur
Femur
N
0
0.75
1.5
3 Meters
Legend
Deland Basestation (DLND)
Leesburg Basestation (LEES)
Collection date: 2/11/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Os coxa
Os coxa
Os coxa
L-vert
Os coxa
N
0 5 10 20 Centimeters

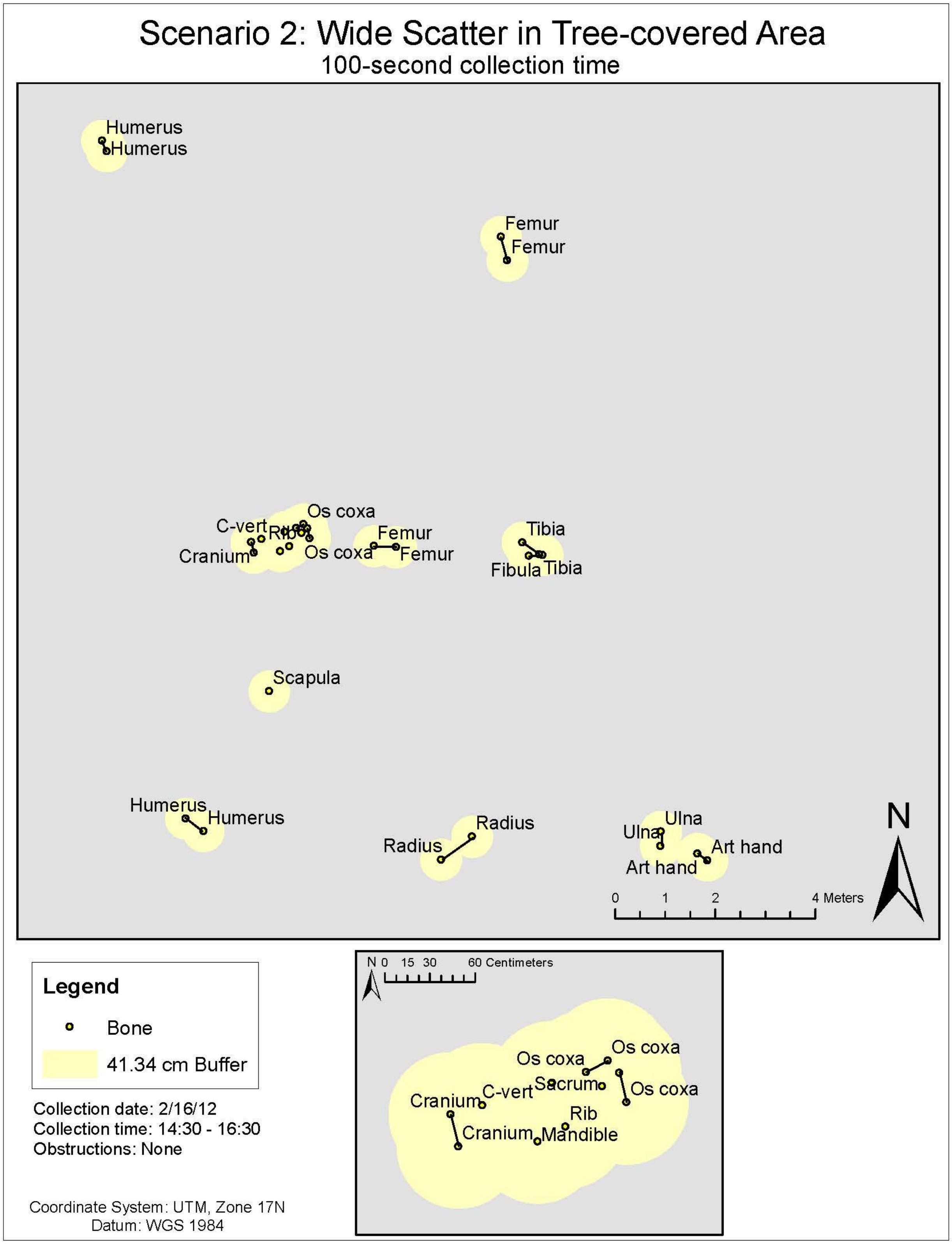

Scenario 1 Processed with DLND and Multiple Basestations
100-second collection time
Radius
Ulna
Ulna
Humerus
Humerus
Tibia
Tibia
Femur
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Rib
L-vert
Rib
T-vert
Os coxa
Sacrum
L-vert
Cranium
Rib
Os coxa
Mandible
Femur
Femur
N
0 0.75 1.5 3 Meters
Legend
Deland Basestation (DLND)
Multiple Basestations (DLND, CCV6, LEES)
Collection date: 2/11/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Os coxa
Os coxa
Os coxa
L-vert
Os coxa
N
0 5 10 20 Centimeters

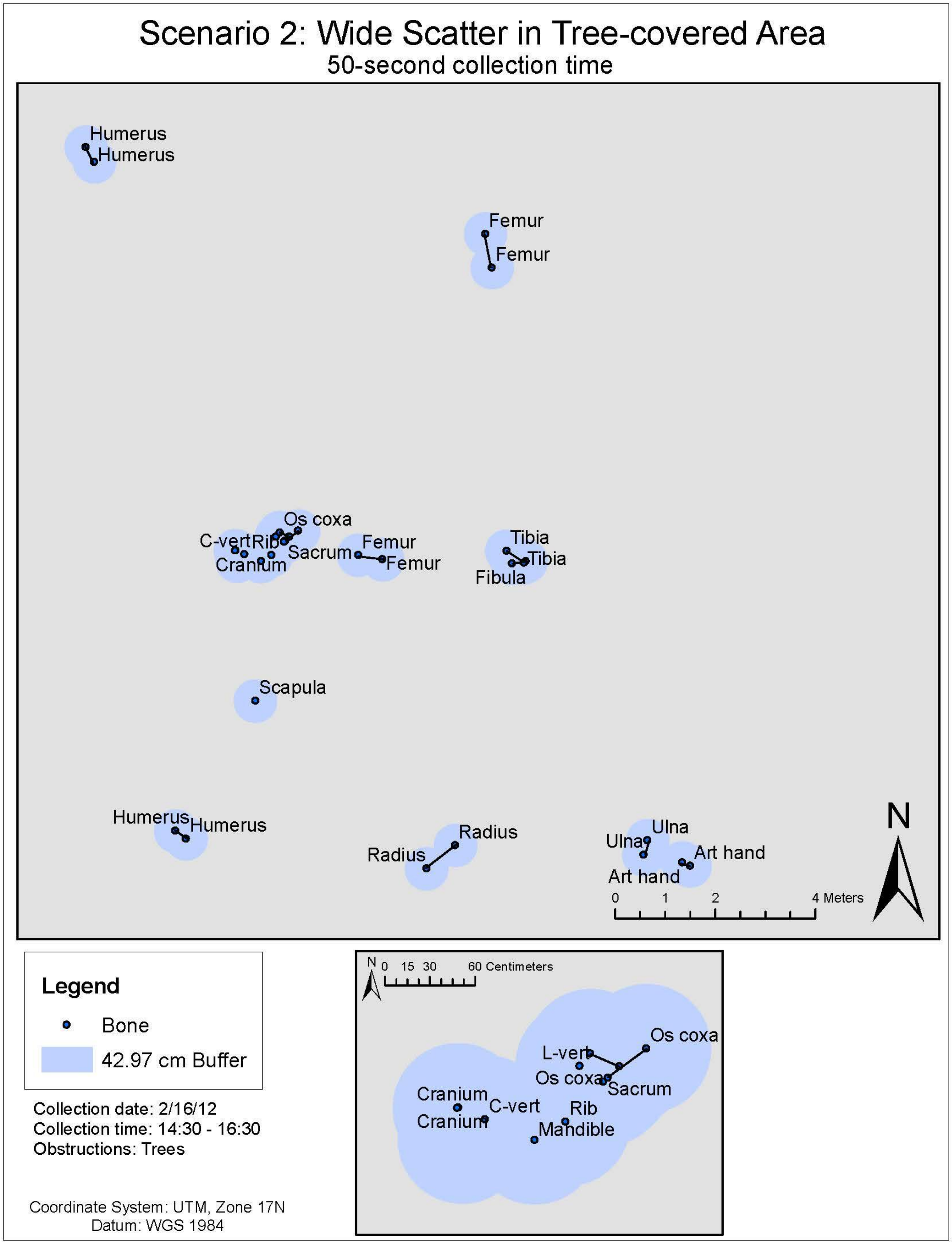


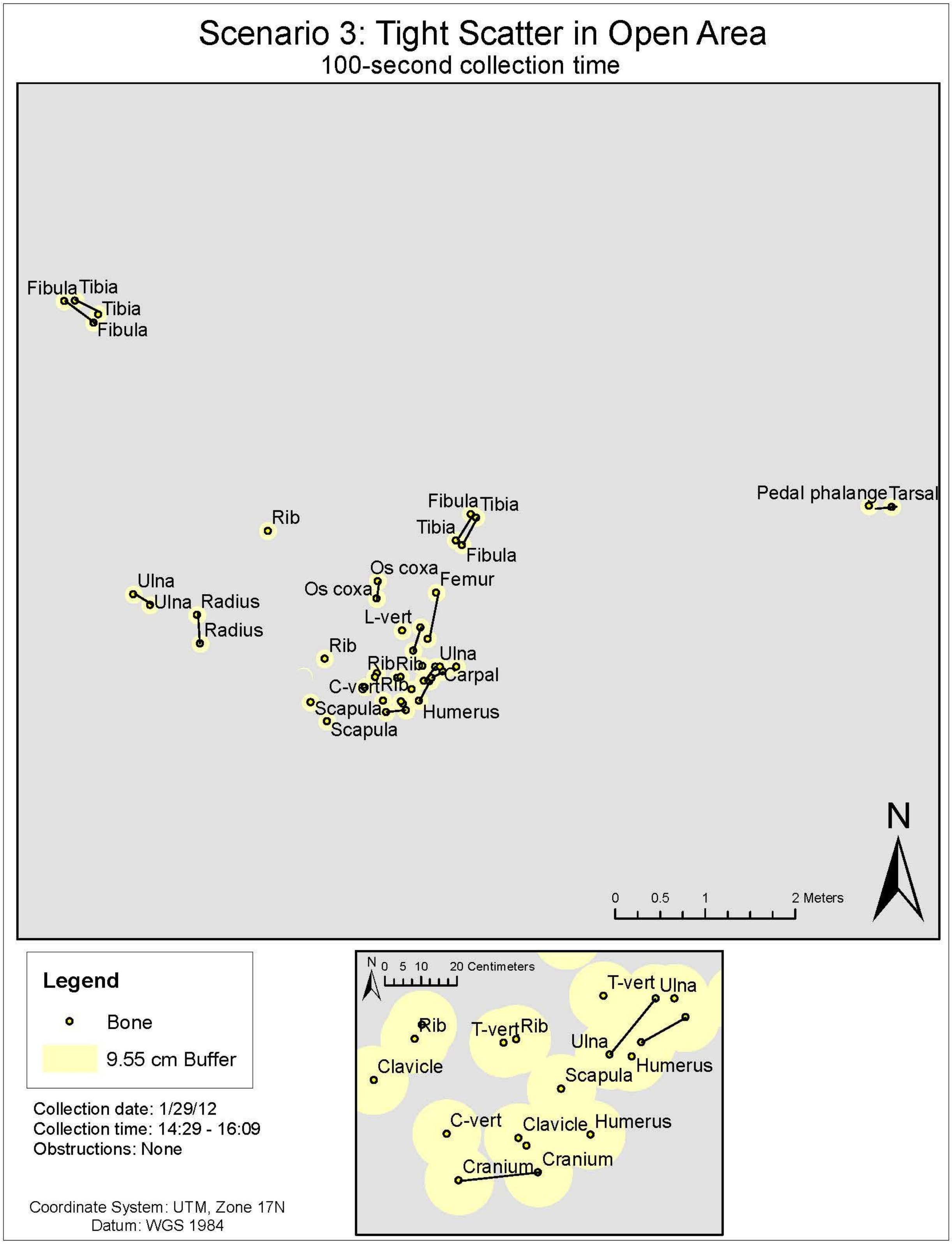
Scenario 1 Processed with DLND and Multiple Basestations
50-second collection time
Ulna
Ulna
Radius
Radius
Humerus
Humerus
Tibia
Tibia
Femur
Femur
Fibula
Scapula
T-vert
Rib
T-vert
Clavicle
Rib
L-vert
Rib
T-vert
Os coxa
Os coxa
Sacrum
Cranium
L-vert
Rib
Os coxa
Mandible
N
Femur
Femur
0
0.75
1.5
3 Meters
Legend
Deland Basestation (DLND)
Multiple Basestations (DLND, CCV6, LEES)
Os coxa
Os coxa
Os coxa
L-vert
Os coxa
N
0 5 10 20 Centimeters
Collection date: 2/11/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984

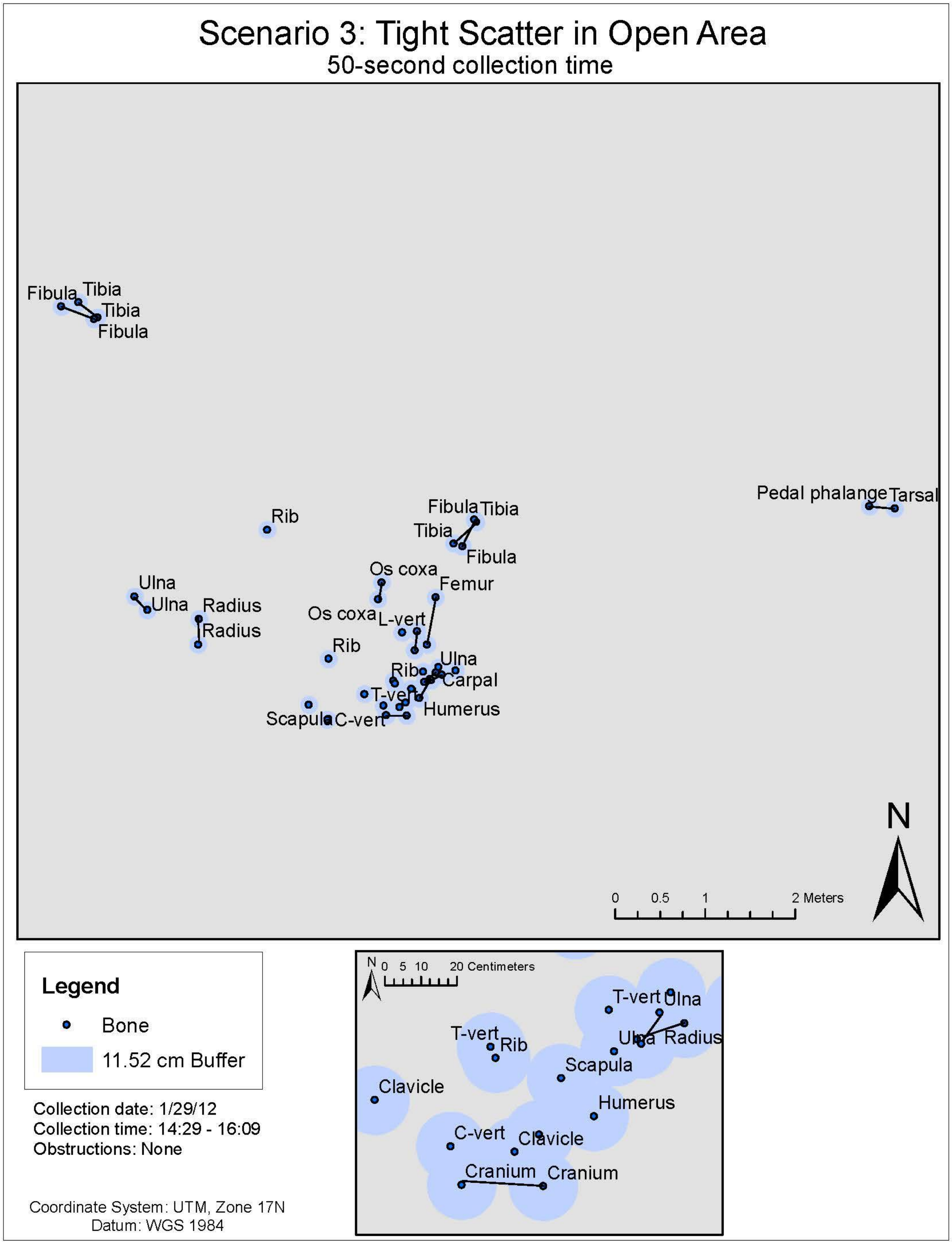

Scenario 1A and 1B: Wide Scatter in Open Area
100-second collection time
Radius
Ulna
Ulna
Radius
Humerus
Humerus
Femur
Tibia
Femur
Fibula
Tibia
Scapula
T-vert
Rib
T-vert
Clavicle
Rib
L-vert
Rib
T-vert
Os coxa
Sacrum
Cranium
L-vert
Rib
Os coxa
Mandible
N
Femur
Femur
0 0.75 1.5 3 Meters
Legend
Day 1
Day 2
Os coxa
Os coxa
Os coxa
L-vert
N
0 5 10 20 Centimeters
Collection date: 2/11/12 and 2/12/12
Collection time: 14:04 - 16:38 and 14:12 - 16:32
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984

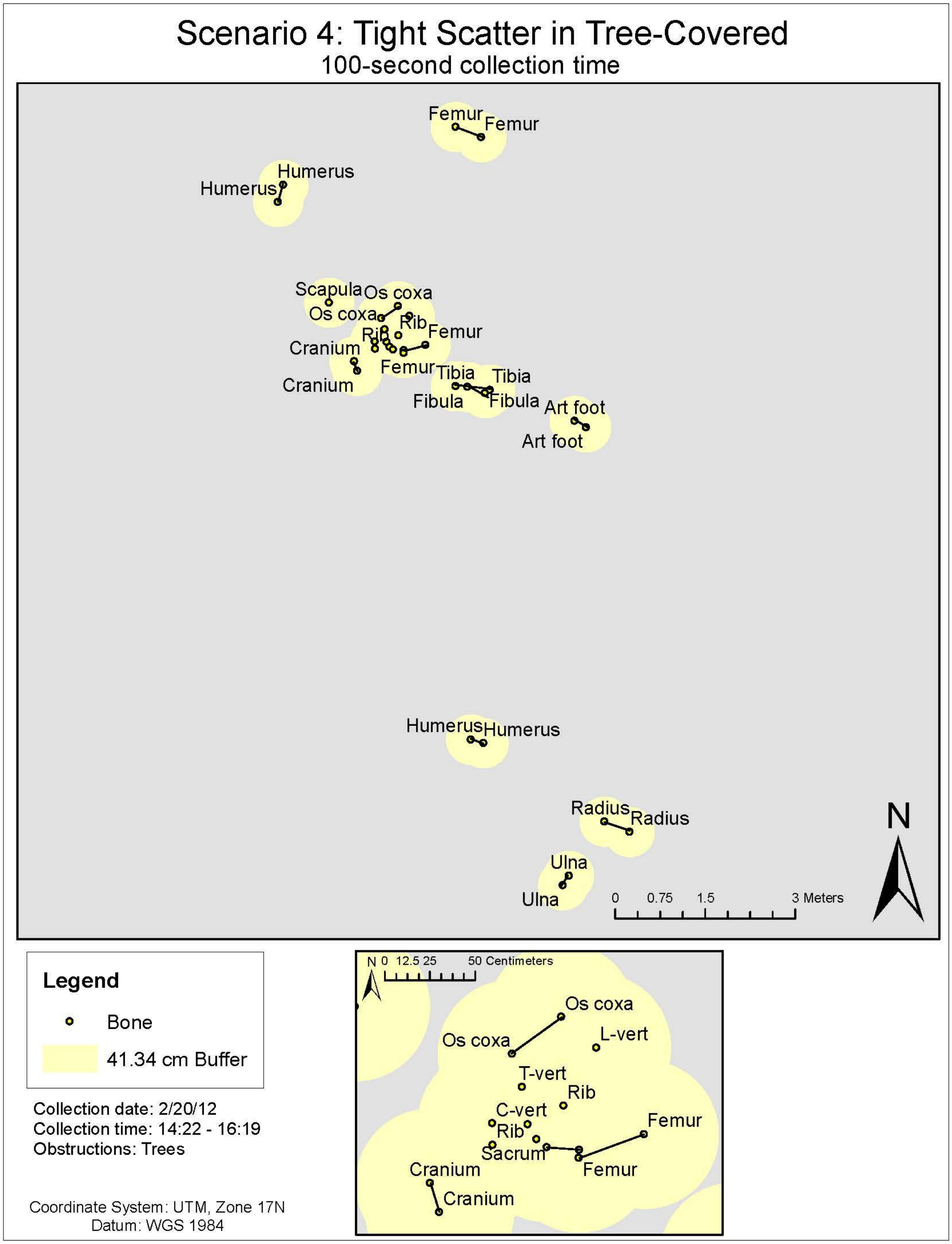

Scenario 1A and 1B: Wide Scatter in Open Area
50-second collection time
Ulna
Ulna
Radius
Radius
Humerus
Humerus
Tibia
Femur
Scapula
T-vert
Rib
T-vert
Clavicle
Rib
L-vert
Rib
T-vert
Os coxa
Os coxa
Sacrum
Cranium
Rib
L-vert
Os coxa
Mandible
Femur
Femur
N
0 0.75 1.5 3 Meters
Legend
Day 1
Day 2
Collection date: 2/11/12 and 2/12/12
Collection time: 14:04 - 16:38 and 14:12 - 16:32
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Os coxa
Os coxa
Os coxa
L-vert
N
0 5 10 20 Centimeters

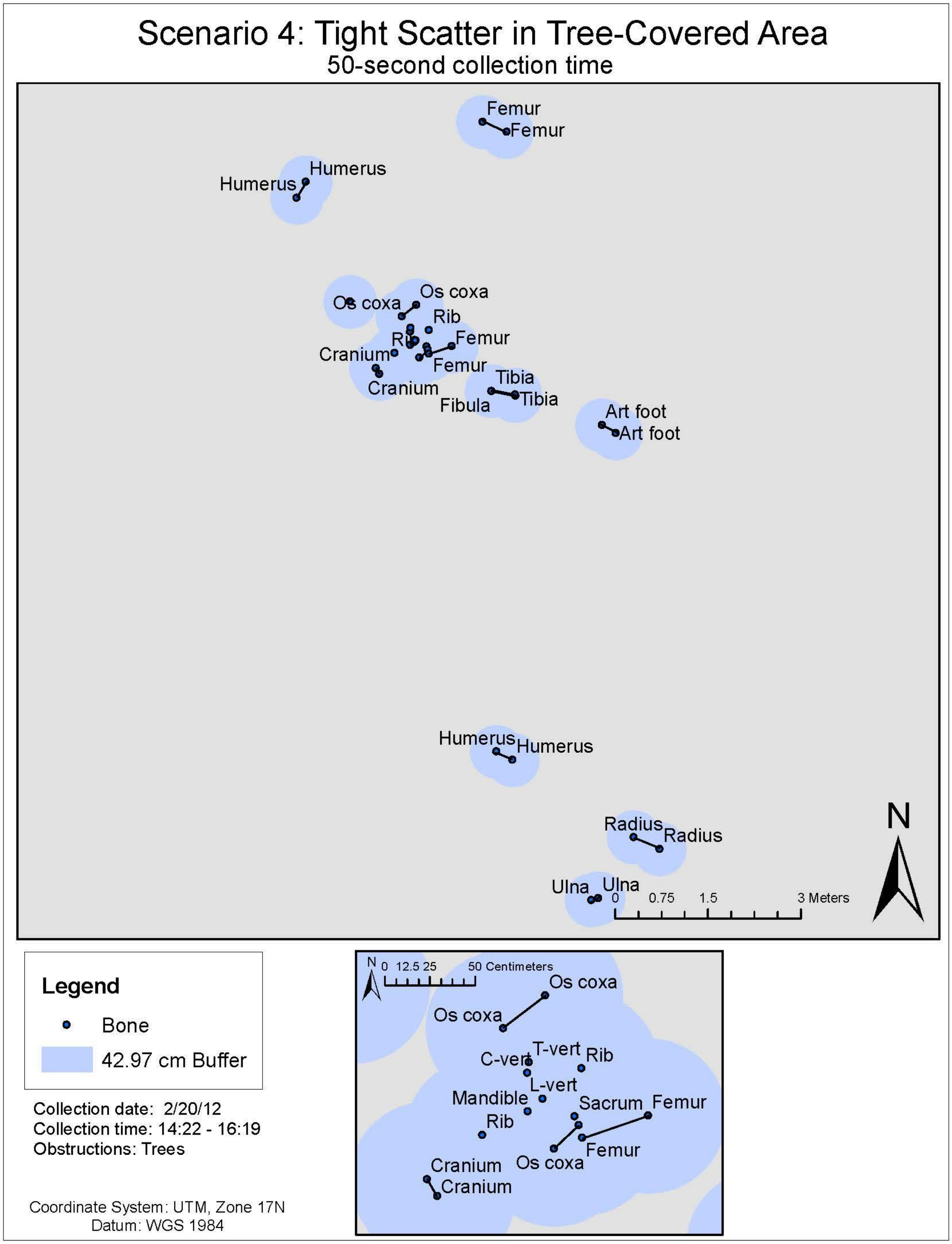

Scenario 2: Wide Scatter in Tree-covered Area
100-second collection time
Humerus
Humerus
Femur
Femur
Os coxa
C-vert
Rib
Cranium
Os coxa
Femur
Femur
Tibia
Fibula
Tibia
Scapula
Humerus
Humerus
Radius
Radius
Ulna
Ulna
Art hand
Art hand
N
0 1 2 4 Meters
N 0 15 30 60 Centimeters
Os coxa
Os coxa
Sacrum
Os coxa
Cranium
C-vert
Rib
Cranium
Mandible
Legend
Bone
41.34 cm Buffer
Collection date: 2/16/12
Collection time: 14:30 - 16:30
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984

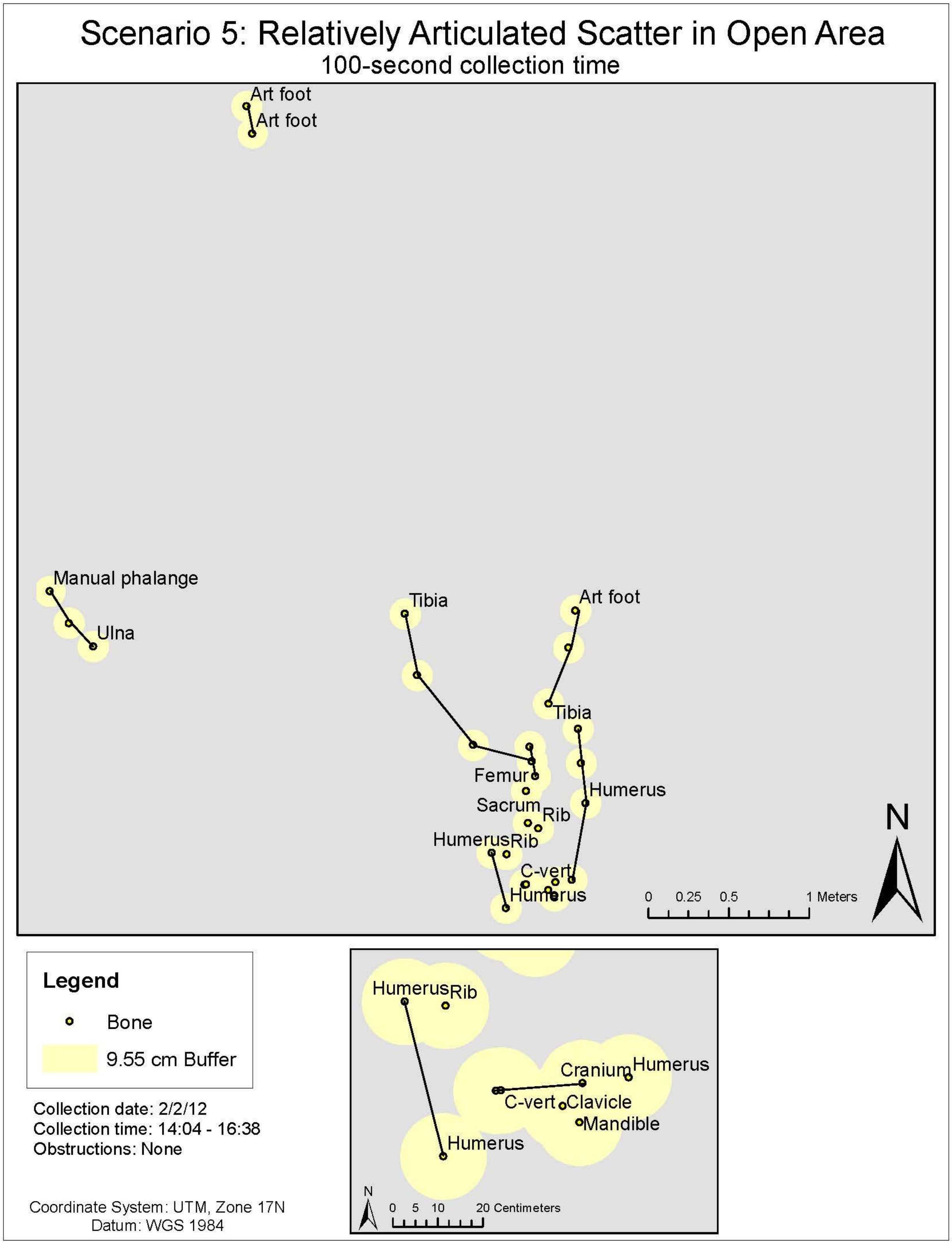

Scenario 2: Wide Scatter in Tree-covered Area
50-second collection time
Humerus
Humerus
Femur
Femur
Os coxa
C-vert
Rib
Femur
Sacrum
Femur
Cranium
Tibia
Tibia
Fibula
Scapula
Humerus
Humerus
Radius
Radius
Ulna
Ulna
Art hand
Art hand
N
0 1 2 4 Meters
Legend
Bone
42.97 cm Buffer
Collection date: 2/16/12
Collection time: 14:30 - 16:30
Obstructions: Trees
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0 15 30 60 Centimeters
Os coxa
L-vert
Os coxa
Sacrum
Cranium
C-vert
Rib
Cranium
Mandible


Scenario 3: Tight Scatter in Open Area
100-second collection time
Fibula
Tibia
Tibia
Fibula
Rib
Fibula
Tibia
Tibia
Fibula
Pedal phalange
Tarsal
Ulna
Ulna
Radius
Radius
Os coxa
Os coxa
Femur
L-vert
Rib
Rib
Rib
Ulna
C-vert
Rib
Carpal
Scapula
Humerus
Scapula
N
0
0.5
1
2 Meters
Legend
Bone
9.55 cm Buffer
Collection date: 1/29/12
Collection time: 14:29 - 16:09
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0 5 10 20 Centimeters
T-vert
Ulna
Rib
T-vert
Rib
Ulna
Clavicle
Humerus
Scapula
C-vert
Clavicle
Humerus
Cranium
Cranium

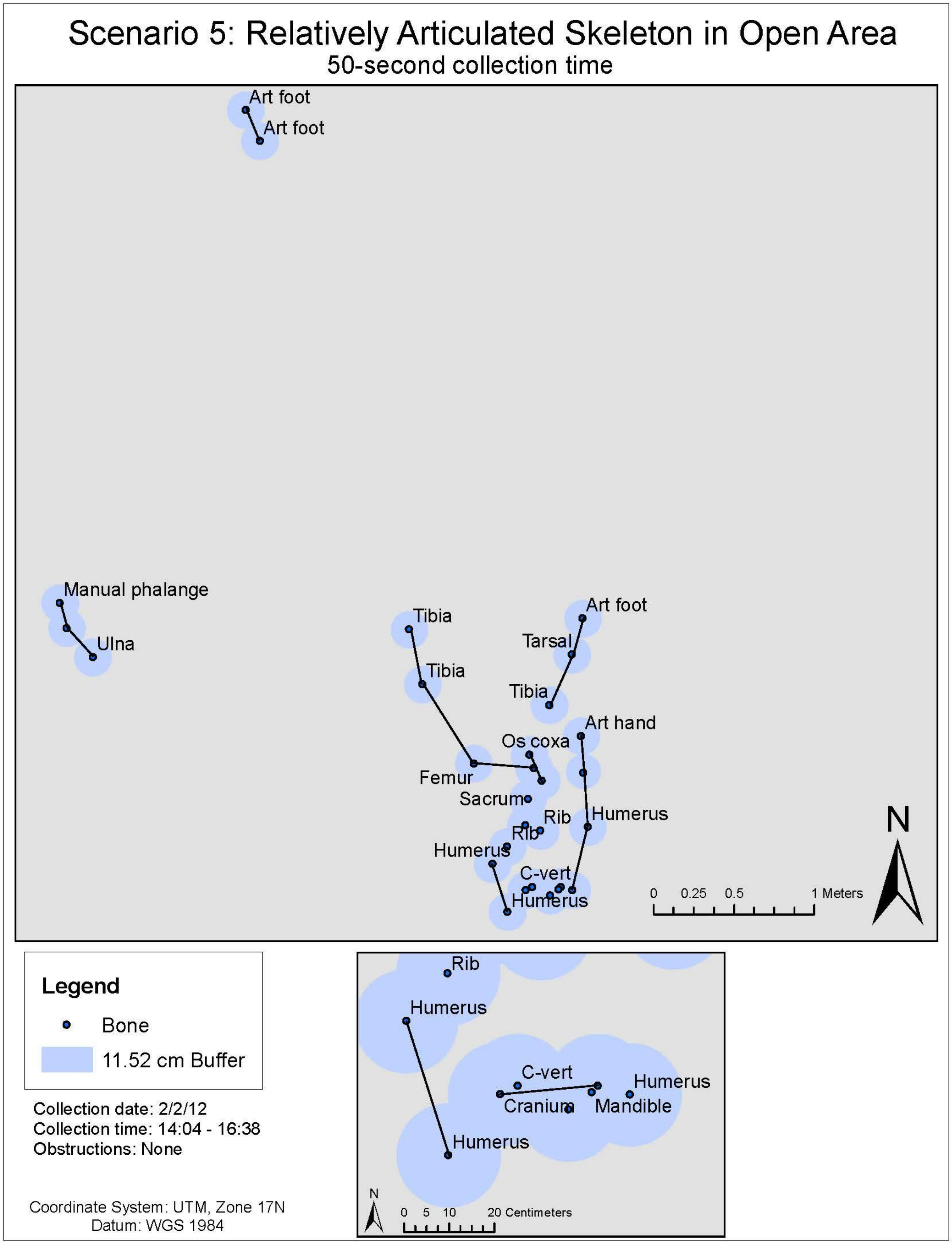

Scenario 3: Tight Scatter in Open Area
50-second collection time
Fibula
Tibia
Tibia
Fibula
Rib
Fibula
Tibia
Tibia
Fibula
Pedal phalange
Tarsal
Os coxa
Femur
Ulna
Ulna
Radius
Radius
Os coxa
L-vert
Rib
Rib
Ulna
Carpal
T-vert
Humerus
Scapula
C-vert
N
0
0.5
1
2 Meters
Legend
Bone
11.52 cm Buffer
Collection date: 1/29/12
Collection time: 14:29 - 16:09
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0 5 10 20 Centimeters
T-vert
Ulna
Ulna
Radius
T-vert
Rib
Scapula
Clavicle
Humerus
C-vert
Clavicle
Cranium
Cranium

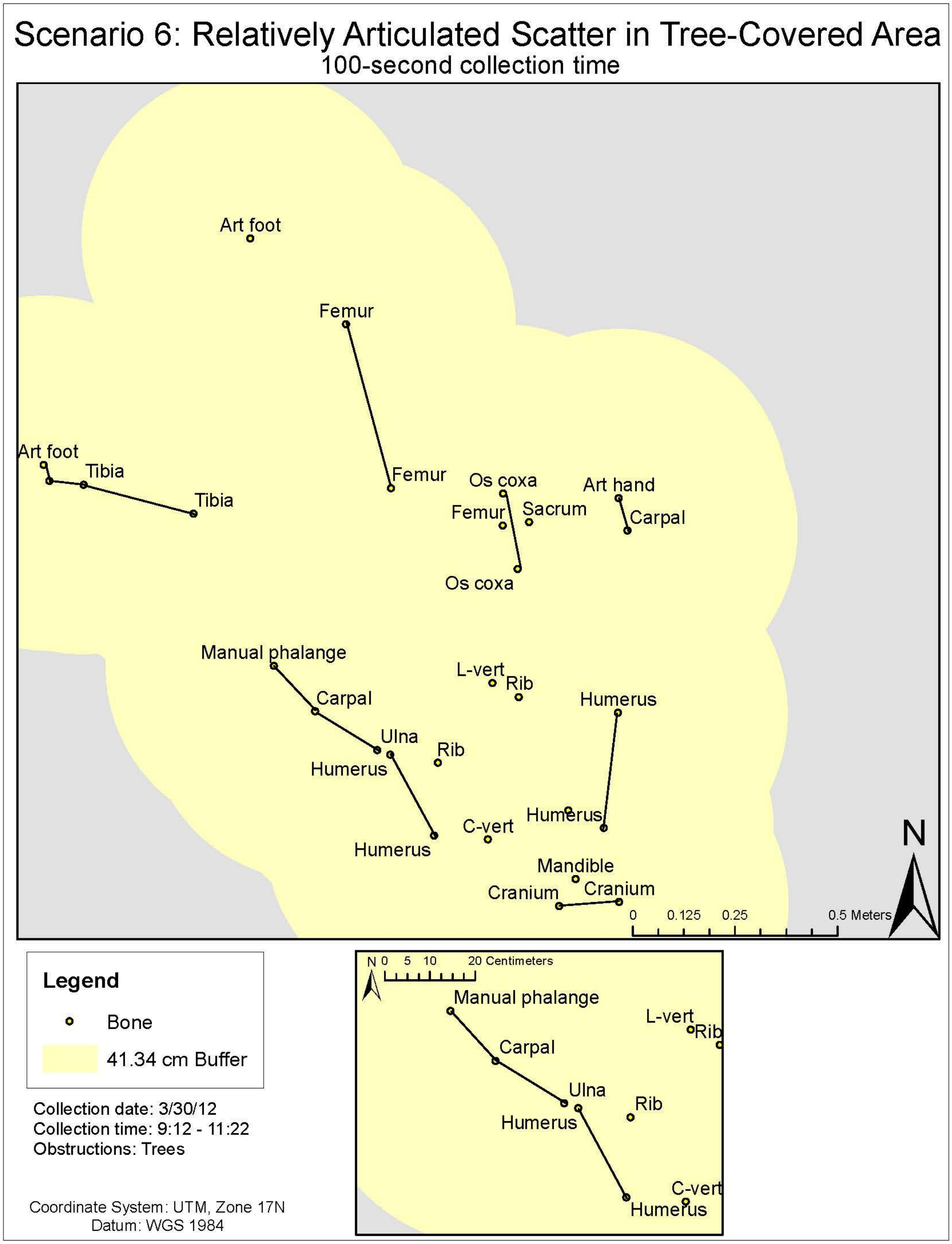

Scenario 4: Tight Scatter in Tree-Covered
100-second collection time
Femur
Femur
Humerus
Humerus
Scapula
Os coxa
Os coxa
Rib
Rib
Femur
Cranium
Femur
Cranium
Tibia
Tibia
Fibula
Fibula
Art foot
Art foot
Humerus
Humerus
Radius
Radius
Ulna
Ulna
0 0.75 1.5 3 Meters
N
Legend
Bone
41.34 cm Buffer
Collection date: 2/20/12
Collection time: 14:22 - 16:19
Obstructions: Trees
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N 0 12.5 25 50 Centimeters
Os coxa
Os coxa
L-vert
T-vert
Rib
C-vert
Rib
Femur
Sacrum
Femur
Cranium
Cranium


Scenario 4: Tight Scatter in Tree-Covered Area
50-second collection time
Femur
Femur
Humerus
Humerus
Os coxa
Os coxa
Rib
Rib
Femur
Cranium
Femur
Cranium
Tibia
Tibia
Fibula
Art foot
Art foot
Humerus
Humerus
Radius
Radius
Ulna
Ulna
0
0.75
1.5
3 Meters
N
Legend
Bone
42.97 cm Buffer
Collection date: 2/20/12
Collection time: 14:22 - 16:19
Obstructions: Trees
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0
12.5
25
50 Centimeters
Os coxa
Os coxa
C-vert
T-vert
Rib
L-vert
Mandible
Sacrum
Femur
Rib
Femur
Cranium
Os coxa
Cranium

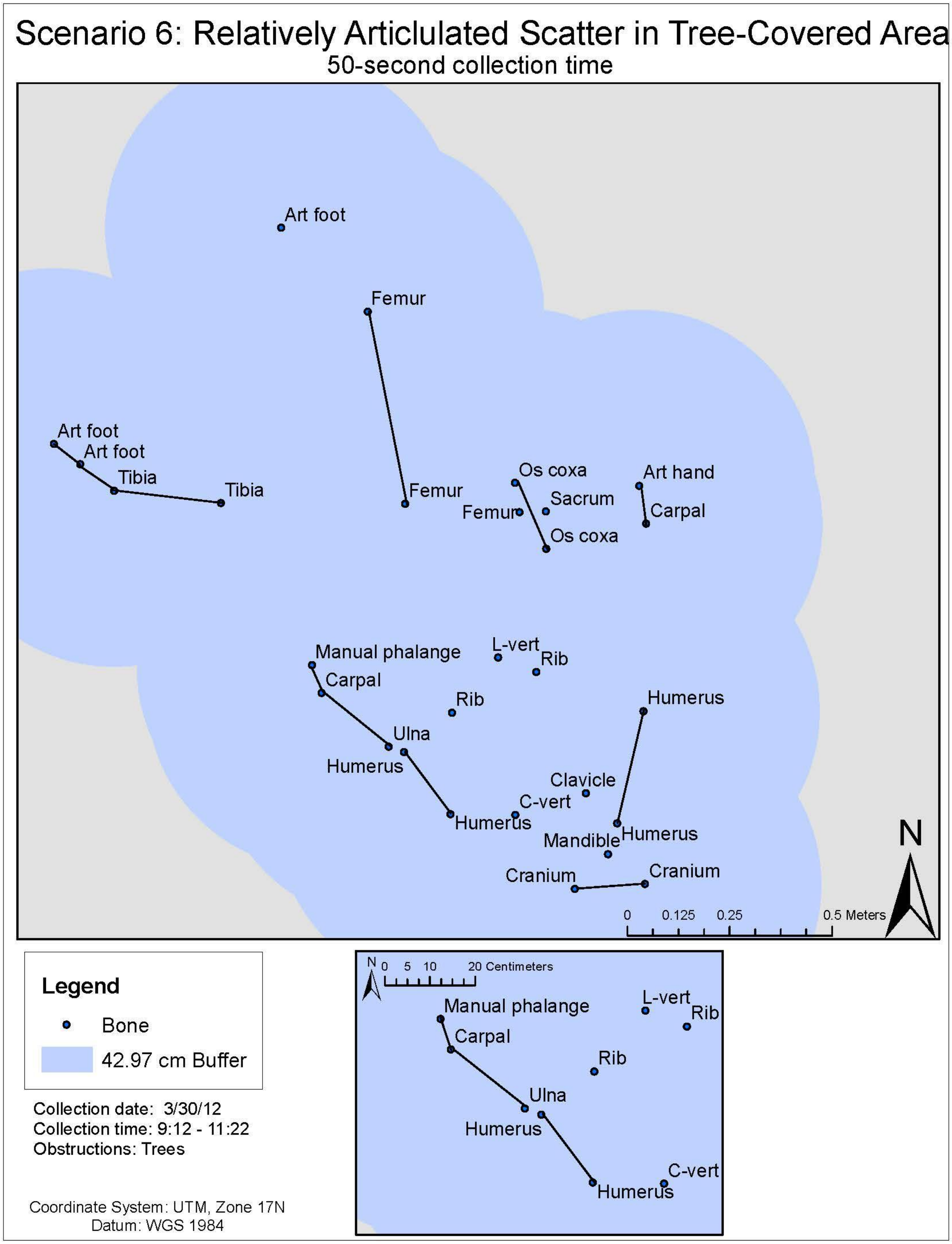


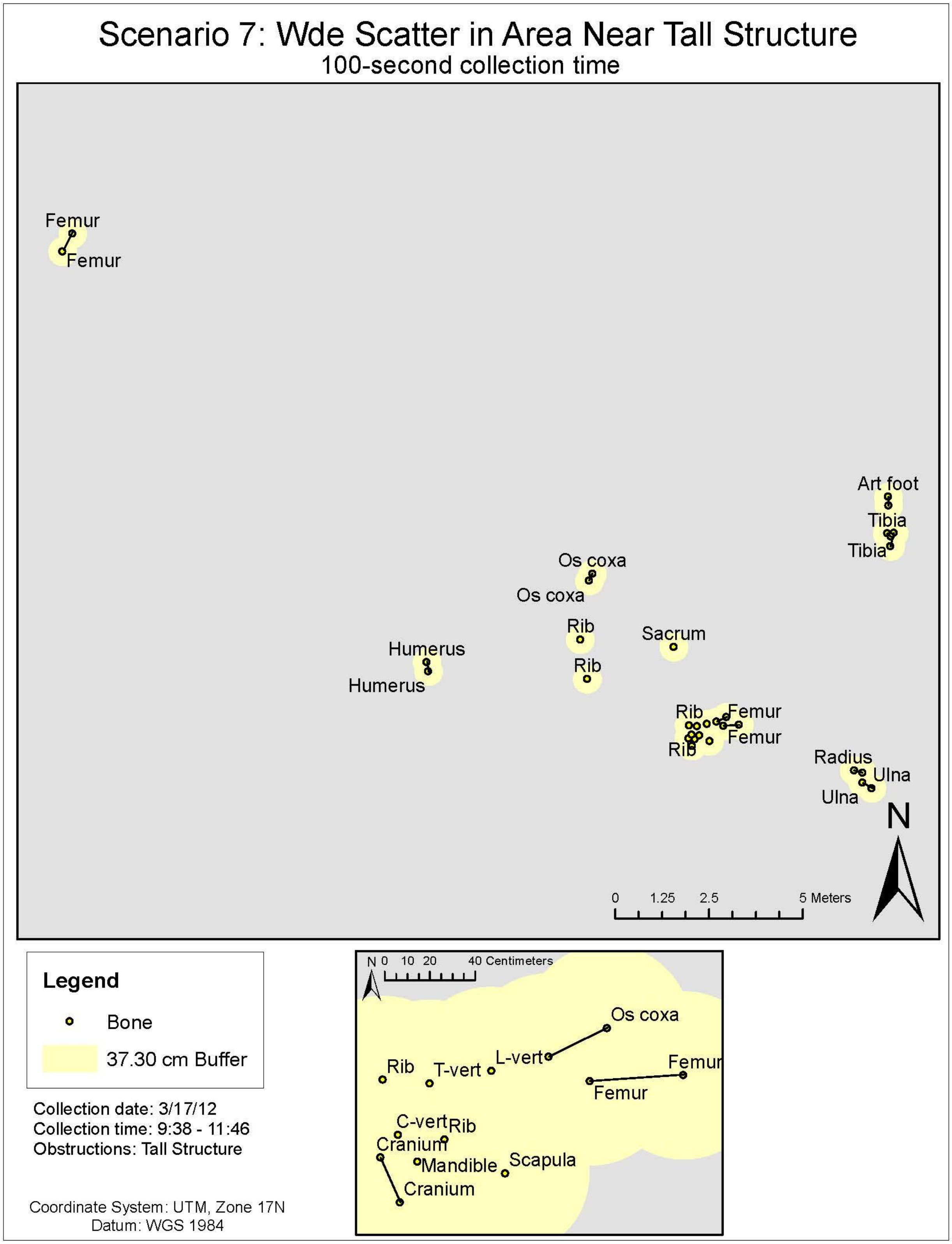
Scenario 5: Relatively Articulated Scatter in Open Area
100-second collection time
Art foot
Art foot
Manual phalange
Ulna
Tibia
Art foot
Tibia
Femur
Humerus
Sacrum
Rib
Humerus
Rib
C-vert
Humerus
0 0.25 0.5 1 Meters
N
Legend
Bone
9.55 cm Buffer
Collection date: 2/2/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Humerus
Rib
Cranium
Humerus
C-vert
Clavicle
Mandible
Humerus
N
0 5 10 20 Centimeters


Scenario 5: Relatively Articulated Skeleton in Open Area
50-second collection time
Art foot
Art foot
Manual phalange
Ulna
Tibia
Tibia
Art foot
Tarsal
Tibia
Art hand
Os coxa
Femur
Sacrum
Rib
Rib
Humerus
Humerus
C-vert
Humerus
N
0 0.25 0.5 1 Meters
Legend
Bone
11.52 cm Buffer
Collection date: 2/2/12
Collection time: 14:04 - 16:38
Obstructions: None
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
Rib
Humerus
C-vert
Humerus
Cranium
Mandible
Humerus
N
0 5 10 20 Centimeters

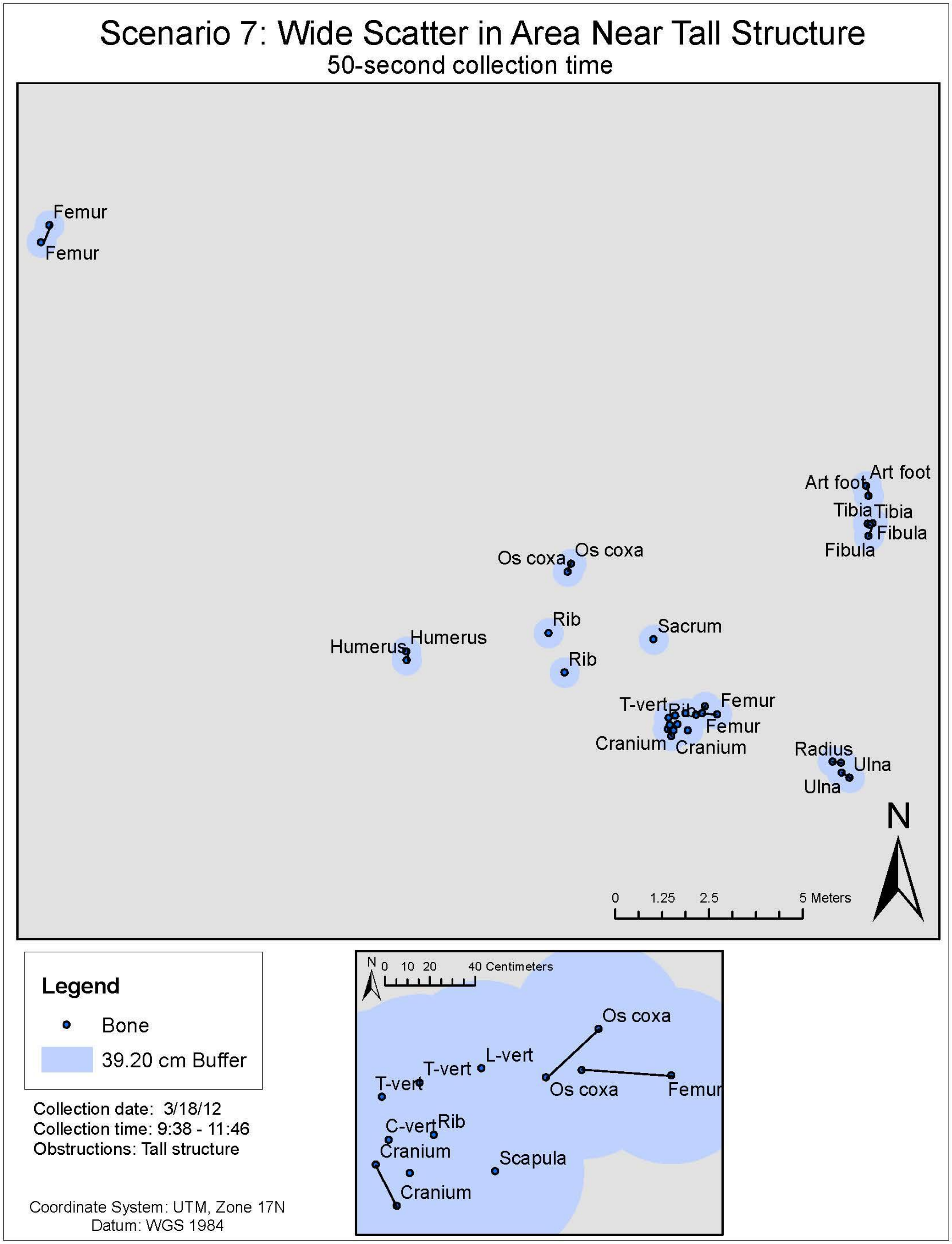


Scenario 6: Relatively Articulated Scatter in Tree-Covered Area
100-second collection time
Art foot
Femur
Art foot
Tibia
Tibia
Femur
Os coxa
Art hand
Femur
Sacrum
Carpal
Os coxa
Manual phalange
L-vert
Rib
Carpal
Humerus
Ulna
Rib
Humerus
Humerus
C-vert
Humerus
Mandible
Cranium
Cranium
N
0
0.125
0.25
0.5 Meters
Legend
Bone
41.34 cm Buffer
Collection date: 3/30/12
Collection time: 9:12 - 11:22
Obstructions: Trees
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N 0 5 10 20 Centimeters
Manual phalange
L-vert
Rib
Carpal
Ulna
Rib
Humerus
C-vert
Humerus

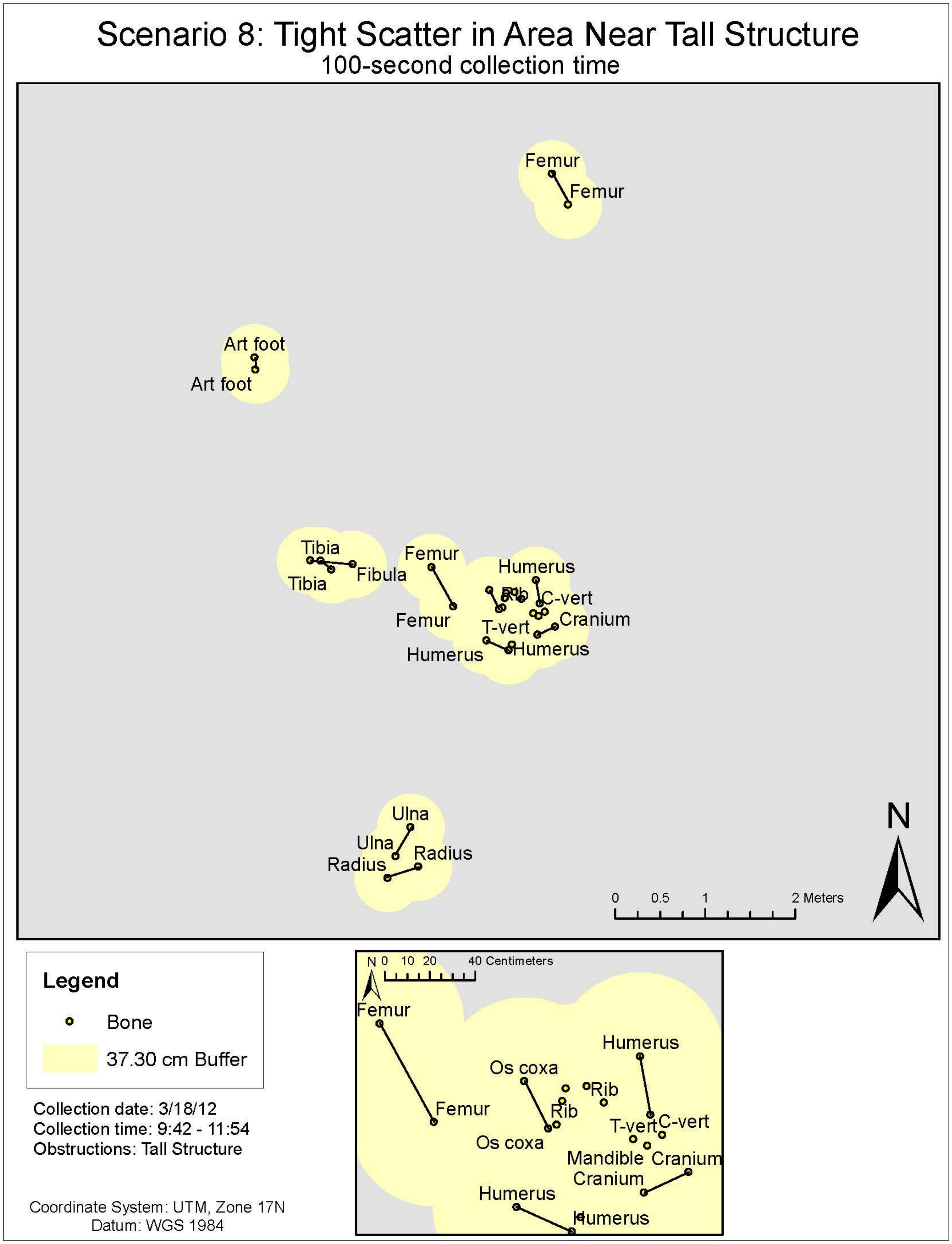

Scenario 6: Relatively Articlulated Scatter in Tree-Covered Area
50-second collection time
Art foot
Femur
Art foot
Art foot
Tibia
Tibia
Femur
Os coxa
Sacrum
Femur
Os coxa
Art hand
Carpal
Manual phalange
L-vert
Rib
Carpal
Rib
Humerus
Ulna
Humerus
Clavicle
C-vert
Humerus
Mandible
Humerus
Cranium
Cranium
N
0 0.125 0.25 0.5 Meters
Legend
Bone
42.97 cm Buffer
Collection date: 3/30/12
Collection time: 9:12 - 11:22
Obstructions: Trees
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N 0 5 10 20 Centimeters
Manual phalange
L-vert
Rib
Carpal
Rib
Ulna
Humerus
C-vert
Humerus

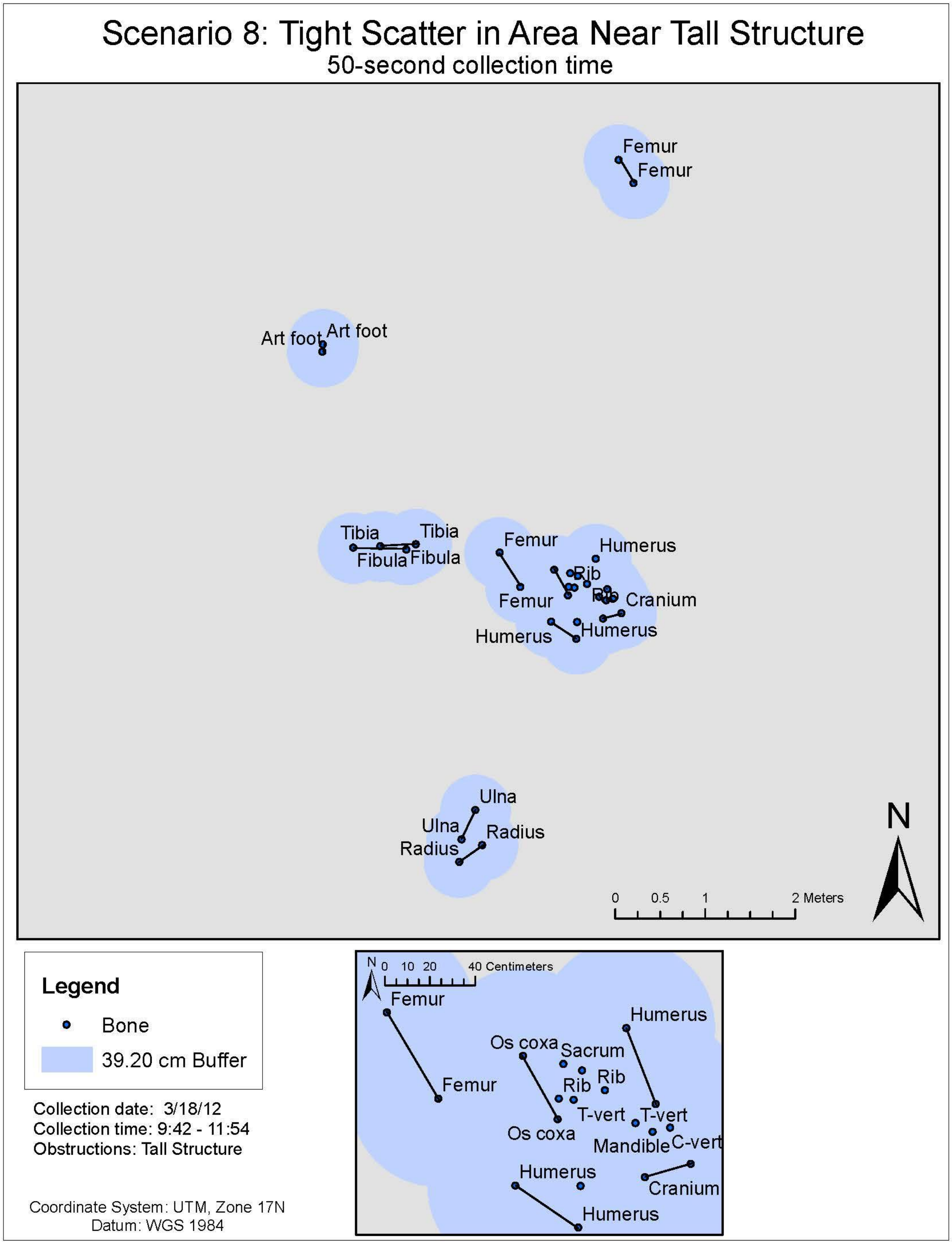


Scenario 7: Wde Scatter in Area Near Tall Structure
100-second collection time
Femur
Femur
Art foot
Tibia
Tibia
Os coxa
Os coxa
Rib
Sacrum
Humerus
Rib
Humerus
Rib
Femur
Femur
Rib
Radius
Ulna
Ulna
N
0 1.25 2.5 5 Meters
Legend
Bone
37.30 cm Buffer
Collection date: 3/17/12
Collection time: 9:38 - 11:46
Obstructions: Tall Structure
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N 0 10 20 40 Centimeters
Os coxa
Rib
T-vert
L-vert
Femur
Femur
C-vert
Rib
Cranium
Mandible
Scapula
Cranium

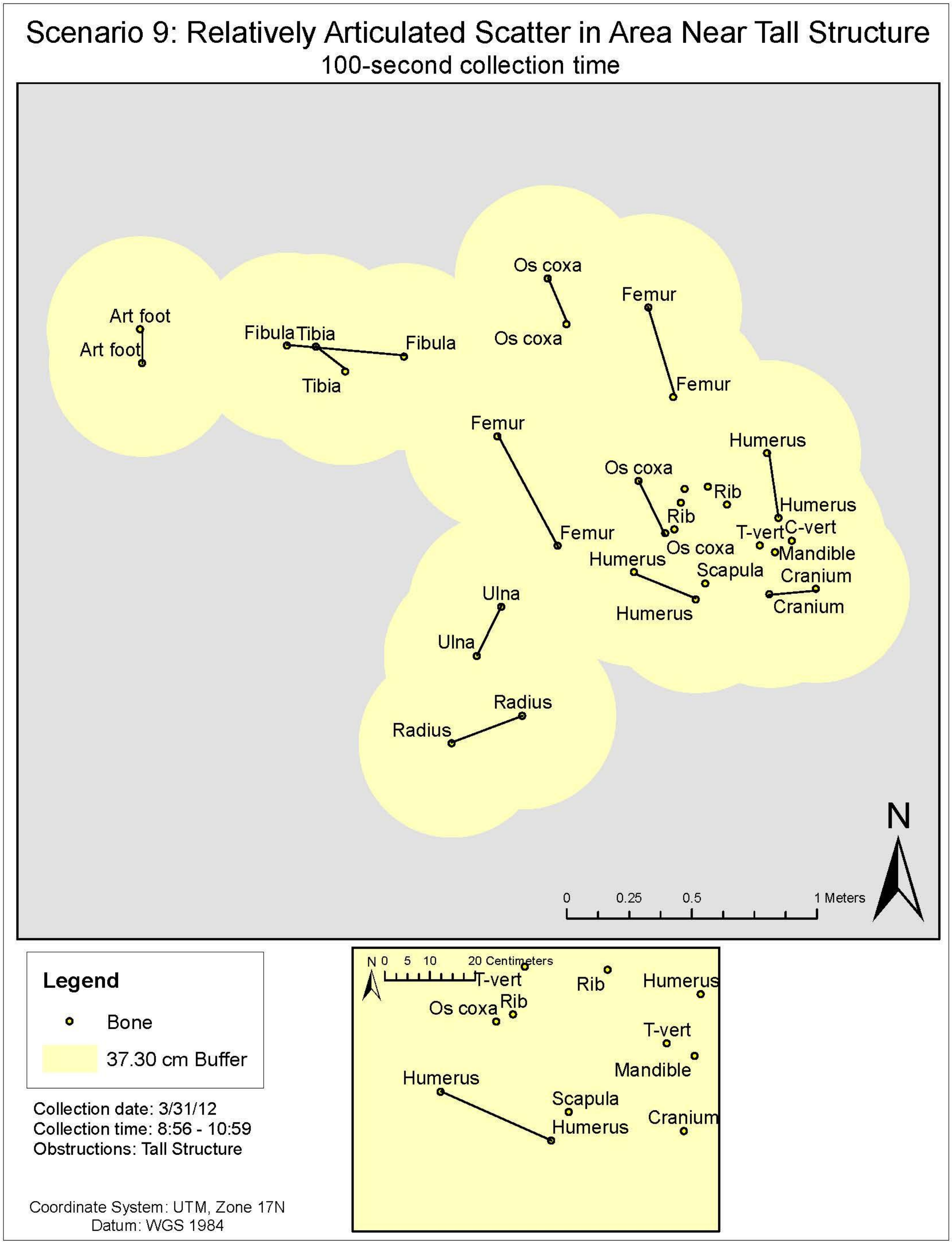


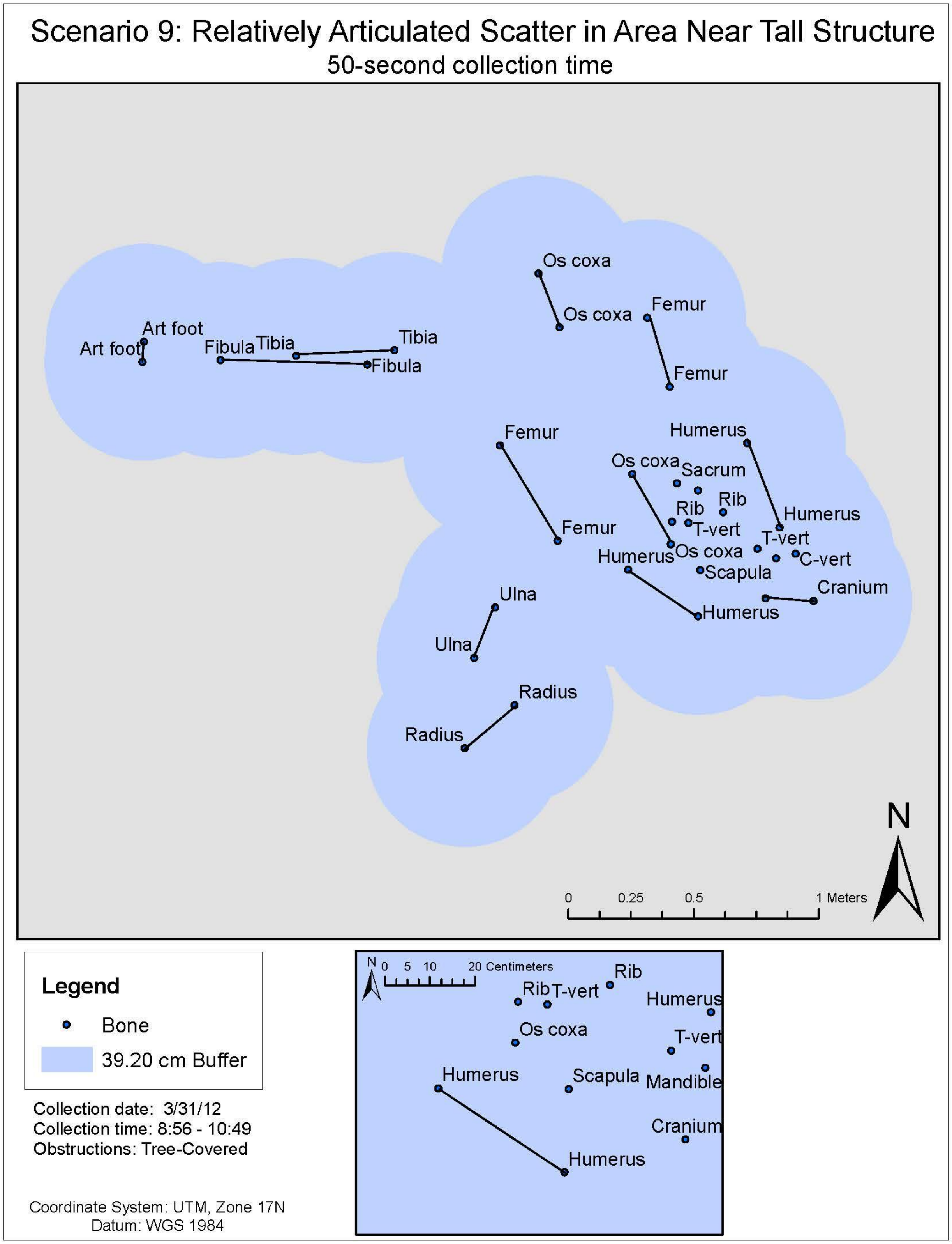
Scenario 7: Wide Scatter in Area Near Tall Structure
50-second collection time
Femur
Femur
Art foot
Art foot
Tibia
Tibia
Fibula
Fibula
Os coxa
Os coxa
Rib
Rib
Sacrum
Humerus
Humerus
T-vert
Rib
Femur
Femur
Cranium
Cranium
Radius
Ulna
Ulna
N
0
1.25
2.5
5 Meters
Legend
Bone
39.20 cm Buffer
Collection date: 3/18/12
Collection time: 9:38 - 11:46
Obstructions: Tall structure
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0 10 20 40 Centimeters
Os coxa
L-vert
T-vert
T-vert
Os coxa
Femur
C-vert
Rib
Cranium
Scapula
Cranium


Scenario 8: Tight Scatter in Area Near Tall Structure
100-second collection time
Femur
Femur
Art foot
Art foot
Tibia
Tibia
Fibula
Femur
Femur
Humerus
Rib
C-vert
T-vert
Cranium
Humerus
Humerus
Ulna
Ulna
Radius
Radius
N
0 0.5 1 2 Meters
Legend
Bone
37.30 cm Buffer
Collection date: 3/18/12
Collection time: 9:42 - 11:54
Obstructions: Tall Structure
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N 0 10 20 40 Centimeters
Femur
Femur
Humerus
Os coxa
Rib
Rib
T-vert
C-vert
Os coxa
Mandible
Cranium
Cranium
Humerus
Humerus



Scenario 8: Tight Scatter in Area Near Tall Structure
50-second collection time
Femur
Femur
Art foot
Art foot
Tibia
Tibia
Fibula
Fibula
Femur
Humerus
Rib
Rib
Femur
Cranium
Humerus
Humerus
Ulna
Ulna
Radius
Radius
N
0 0.5 1 2 Meters
Legend
Bone
39.20 cm Buffer
Collection date: 3/18/12
Collection time: 9:42 - 11:54
Obstructions: Tall Structure
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0 10 20 40 Centimeters
Femur
Humerus
Os coxa
Sacrum
Femur
Rib
Rib
T-vert
T-vert
Os coxa
Mandible
C-vert
Humerus
Cranium
Humerus


Scenario 9: Relatively Articulated Scatter in Area Near Tall Structure
100-second collection time
Art foot
Art foot
Fibula
Tibia
Tibia
Fibula
Os coxa
Os coxa
Femur
Femur
Femur
Femur
Humerus
Humerus
Os coxa
Rib
Rib
Os coxa
T-vert
C-vert
Mandible
Humerus
Scapula
Cranium
Cranium
Humerus
Ulna
Ulna
Radius
Radius
N
0
0.25
0.5
1 Meters
Legend
Bone
37.30 cm Buffer
Collection date: 3/31/12
Collection time: 8:56 - 10:59
Obstructions: Tall Structure
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N 0 5 10 20 Centimeters
T-vert
Rib
Humerus
Os coxa
Rib
T-vert
Mandible
Humerus
Scapula
Humerus
Cranium


Scenario 9: Relatively Articulated Scatter in Area Near Tall Structure
50-second collection time
Os coxa
Os coxa
Femur
Femur
Art foot
Art foot
Fibula
Tibia
Tibia
Fibula
Femur
Humerus
Os coxa
Sacrum
Rib
Rib
Humerus
T-vert
Femur
T-vert
Humerus
Os coxa
C-vert
Scapula
Cranium
Ulna
Humerus
Ulna
Radius
Radius
N
0 0.25 0.5 1 Meters
Legend
Bone
39.20 cm Buffer
Collection date: 3/31/12
Collection time: 8:56 - 10:49
Obstructions: Tree-Covered
Coordinate System: UTM, Zone 17N
Datum: WGS 1984
N
0 5 10 20 Centimeters
Rib
Rib
T-vert
Humerus
Os coxa
T-vert
Humerus
Scapula
Mandible
Cranium
Humerus

REFERENCES

Bolstad P. 2005. GIS fundamentals: A first text on geographic information systems. 3rd ed. White Bear Lake, Minnesota: Eider Press.

Capra A, Gandolfi S, Laurencich L, Mancini F, Minelli A, Orsini C, and Rodriguez A. 2002. Multidisciplinary approach for archaeological survey: Exploring GPS methods in landscape archaeology studies. J Cult Heritage 3: 93-99.

Chapman H, Van de Noort R. 2001. High Resolution Wetland Prospection, using GPS and GIS: Landscape Studies at Common Sutton (South Yorkshire) and Meare Village East (Somerset). J Arch Sci 28: 365-375.

Clarke K. 1995. Analytic and computer cartography. 2nd ed. Upper Saddle River, NJ: Prentice Hall.

Collier P, Dominic F, and Pearson A. 1995 GIS Mapping for an Integrated Ecological and Archaeological Study. The Cart J 32: 137-142.

Conolly J, Lake M. 2006. Geographical information systems in archaeology. Cambridge Univ Pr.

Dirkmaat DC, Cabo LL, Ousley SD, Symes SA. 2008. New perspectives in forensic anthropology. Am J Phys Anthropol 137(S47):33-52.

Dupras TL, Schultz JJ, Wheeler SM, Williams LJ. 2011. Forensic recovery of human remains: Archaeological approaches. Boca Raton, FL: CRC Press.

El-Rabbany A. 2006. Introduction to GPS: The global positioning system. 2nd ed. Norwood, MA: Arctech House, Inc.

Environmental Systems Research Institute (ESRI). 1990. Understanding GIS: The ARC/INFO method. Redlands, California: Environmental Systems Research Institute.

Fenwick, Helen. 2004. Ancient Roads and GPS survey: Modelling the Amarna Plain. Antiquity 78 (302): 880-885.

France DL, Griffin TJ, Swanburg JG, Lindemann JW, Davenport GC, Trammell V, Armbrust CT, Kondratieff B, Nelson A, Castellano K and others. 1992. A multidisciplinary approach to the detection of clandestine graves. Journal of Forensic Sciences 37(6):1445-1458.

Gao J. 2002. Integration of GPS with remote sensing and GIS: reality and prospect. J Photogram Eng Remote Sens 68(5):447-453.

Gardner RM. 2004. Practical crime scene processing and investigation. Boca Raton, FL: CRC Press.

Graettinger AJ, Rushing TW, McFadden J. 2001. Evaluation of inexpensive global positioning system units to improve crash location data. Transport Research Rec 1746:94-101.

Hester TR, Shafer HJ, Feder KL. 2009. Field methods in archaeology. 7th ed. Walnut Creek, CA: Lest Coast Press, Inc.

Johnson CE, Barton CC. 2004. Where in the world are my field plots? using GPS effectively in environmental field studies. Frontiers in Ecology and the Environment 2(9):475-482.

Lechner W, Baumann S. 2000. Global navigation satellite systems. Comput Electron Agric 25(1-2):67-85.

Listi GA, Manhein MH, Leitner M. 2003. The next utility in field recovery of scattered remains. [abstract] Proc Am Acad Forensic Sci 2003:271-272.

Listi GA, Manhein MH, Leitner M. 2007. Use of the global positioning system in the field recovery of scattered human remains. J Forensic Sci 52(1):11-15.

Lowe DW, Burns BA. 1998. Using GPS and GIS to create a historic base map. Cult Res Man 21(5):38-39.

Manhein MH, Listi, GA, Leitner M. 2006. The application of geographic information system and spatial analysis to assess dumped and subsequently scattered human remains. J Forensic Sco 51(3):469-474.

Napton LK, Greathouse EA. 2009. Archaeological mapping, site grids, and surveying. In: Hester TR, Shafer HJ, Feder KL, editors. Field Methods in Archaeology. 7th ed. Walnut Creek, CA: Left Coast Press. p 177-234.

Robeson J, personal communication, Trimble Certified Trainer at GPServ Inc, March 12, 2012.

Sando T, Mussa R, Sobanjo J, Spainhour L. 2005. Quantification of the accuracy of low priced GPS receivers for crash location. J Trans Res For 44(2):19-32.

Spencer J, Frizzelle BG, Page PH, Vogler JB. 2003. Global positioning system: A field guide for the social sciences. Malden, MA: Blackwell Publishing Ltd.

Spradley MK, Hamilton MD, Giordano A. 2011. Spatial patterning of vulture scavenged human remains. Forensic Sci Int December: 1-9.

Trimble Navigation Limited. 2004. Why postprocess GPS data? Mapping and GIS White Paper. Westminster,CO: Trimble Navigation Limited.

Trimble Navigation Limited. 2009. GeoExplorer 2002 Series User Guide. Westminster,CO: Trimble Navigation Limited.

Wheatley D, Gillings M. 2002. Spatial technology and archaeology: The archaeological applications of GIS. Boca Raton, FL: CRC Press.

Wu H, Sando T, Mussa R, Sobanjo J, and Spainhour L. 2004. GPS/GIS integration for improving crash location data accuracy, [paper] in Proceedings of ESRI International GIS User Conference, San Diego, California