Archaeological Map of Belize
(ArchMapBZ)
A Geographic Information System for the recording and analysis of archaeological information

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Introduction

The Archaeological Map of Belize is a project to determine precise positions of pairs of intervisable three dimensional control points for mapping on archaeological sites. The purpose is to provide well-defined points in a common coordinate system that will permit analysis on a regional scale. The control points are located using geodetic survey techniques with dual frequency GPS receivers. GPS occupation of features such as road intersections provides the basis for georeferencing a Landsat image of Belize that serves as the base map of the geographical information system.

Grid data

The maps most commonly used by archaeologists in Belize are the 1:50,000 Universal Transverse Mercator Grid series produced under the direction of the Director General of Military Survey, Ministry of Defence, United Kingdom. As a horizontal datum these maps use the North American 1927 datum (NAD27) and the vertical datum is Mean Sea Level (MSL). These conventions provide a strong argument for reporting data in these same systems. However, there are even stronger reasons for favoring the current WGS84 datum and Height Above Ellipsoid (HAE) as the vertical reference. WGS84 is the native system for GPS receivers and the receivers compute the UTM coordinates and the HAE directly from the WGS84 Cartesian Geocentric Coordinates. GPS receivers and post-processing software translate from WGS84 to NAD27 as well as to other coordinate systems and refer to a database to convert from HAE to MSL or to a Geoid model to convert to Orthometric height. Not all equipment and software support well these legacy systems. The greatest consistency given a variety of equipment and software is obtained by adhering to the WGS84 datum. The grounds of consistency and equipment capacity are compelling for reporting the data in WGS84 datum with HAE as the vertical datum.

Instrumentation and methodology

The instrumentation and methodology for gathering field data in this project is based upon and consistent with the guidelines of a number of publications listed in the bibliography. The controlling documents have been the Federal Geodetic Control Subcommittee, Federal Geographic Data Committee (USA), *Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks*, FGDC-STD-007.2-1998, The Intergovernmental Committee on Surveying and Mapping (ICSM), (Australia), *Best Practice Guidelines, Use of the Global Positioning System (GPS) for Surveying Applications*, Version 2.0 - 1 November1997 and The National Geodetic Survey, (USA), *Guidelines for Geodetic Network Surveys Using GPS*. Draft 4, May 15, 2000. These documents are current, detailed in their description of appropriate field methods, and appropriate to the equipment used in this survey project.

Instrumentation

Three GPS receivers are used to collect the data for the control point survey. Two of the receivers are Trimble 4000SSE Geodetic Surveyors These are dual frequency L1/L2 receivers. As configured in this survey with geodetic antennas Trimble specifies a horizontal accuracy of 5 mm + 1ppm times the baseline length and a vertical accuracy of 10 mm + 1ppm times the baseline length. A 4000SE GIS Surveyor was used as a secondary reference receiver in order to produce additional independent baselines and to strengthen the geometry of the solution. For this receiver Trimble specifies an accuracy of +/- 10 mm + 2ppm times the baseline length.[1]

Primary reference station

A 24-channel 4000SSE[2] is used as the primary reference station. It is a dual-frequency receiver equipped with 5 megabytes of memory permitting it to record data at 5-second epochs for approximately 38 hours. The primary reference receiver was operated throughout the duration of the season at the temporary residence of the investigator in Santa Elena, Cayo, Belize. The geodetic antenna was mounted on a 4-meter pole and securely guyed. There was a clear view of the sky from the reference receiver antenna.

Over the course of several years of GPS data gathering in Belize it has typically been most convenient to locate the primary reference station at the residence of the investigator. This has two distinct advantages. The reference station antenna could remain in exactly the same position throughout the season. The alternative has been to reposition the reference station antenna over the same mark for each daily session. The second advantage is the use of household current to power the reference station, backed up by a battery. The disadvantage in this system is that the reference antenna is not positioned on a permanent monument. Each season the coordinates of the reference position are determined by occupation of a nearby permanent monument the coordinates of which had been determined in a prior season. The seasonal temporary reference station locations are designated Temporary Reference Stations (TRS) with a suffix representing the location. The 2001 reference station is designated TRS_AS, the AS being the initials of the owner of the residence where the reference station was located.

Secondary reference station

For each control point survey session a secondary reference receiver is placed on an arbitrary point near to the control points, typically within a hundred meters, to record data for the duration of the session. For each point recorded with the roving receiver the secondary reference receiver provides a second independent baseline. The secondary reference receiver is a 12-channel 4000SE[3] single frequency receiver and therefore requires a lengthier occupation than do the dual frequency receivers to acquire sufficient data for the required double difference fixed solution.

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[1] The GPS receivers were provided by Trimble Navigation Limited, Sunnyvale, CA.

[2] Primary reference GPS receiver

GPS Receiver	Trimble	**GPS Antenna**	Trimble
Model	4000SSE Geodetic Surveyor	**Model**	Geodetic with ground plane
Part No.	18292-01	**Part No.**	14177-00
Serial No.	3244A01763	**Serial No.**	
Firmware	7.29		

[3] Secondary reference GPS receiver

GPS Receiver	Trimble	**GPS Antenna**	Trimble
Model	4000SE GIS Surveyor	**Model**	Compact L1
Part No.	18292-01	**Part No.**	
Serial No.	3301A02301	**Serial No.**	
Firmware	7.23		

The survey protocol described below provides a sufficient occupation time for the secondary reference station to achieve the fixed solution.

Rover GPS station

An 18-channel 4000SSE[4] dual frequency receiver is used as the rover. This receiver is equipped with a geodetic antenna with a ground plane.

Data processing and analysis

All of the GPS data were postprocessed using by the program GeoGenius™ by Spectra Precision Terrasat GmbH, Hoehenkirchen, Germany. This program is designed to integrate terrestrial and satellite data and produces a number of reports permitting evaluation of the quality of the data and providing for the transfer of the data to the GIS system.[5]

The final destination of the data is the GIS platform ArcView™ 3.2 by Environmental Systems Research Institute. A number of ESRI extensions to ArcView™ are also used, most importantly Image Analysis, Spatial Analyst and 3D Analysis.[6]

Field Methods

Survey points and monuments

The objective of the project is to establish on each selected site a pair of recoverable intervisable three dimensional control points. These points must be secure, have a clear view of the sky for GPS measurements, and be separated by a distance sufficient to provide a reliable backsight for a person using an optical total station.[7] Where possible previously established survey monuments are used by this survey. Where the necessary criteria cannot be met by existing monuments this project places monuments in a manner designed to be least likely to damage the archeological record. On sites where monuments have been previously consolidated and where that consolidation is unlikely to be disturbed, the preferred monument is a concrete nail driven into a large and stable concrete slab that is part of the monumental consolidation. Where such locations are not available or do not meet the criteria new monuments are placed in locations deemed unlikely to be the subject of future archaeological investigation. Project monuments are concrete posts 5" x 5" x 18" (13 cm x 13 cm x 46 cm) with a 1/2" iron rebar rod centered in the monument, cut off flush with the top of the monument and dimpled to mark the point. The monument is placed so that it projects only a short distance above the ground level. This design and placement is to prevent the monument from being an impediment or a hazard to people or to livestock. This configuration makes the monuments less visible at a distance and thus more difficult to relocate. Monuments are marked with an aluminum tag fixed to the top of the monument or adjacent to the nail and stamped with a four-digit Station Identification Number.

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[4] Rover GPS receiver

GPS Receiver	Trimble	**GPS Antenna**	Trimble
Model	4000SSE Geodetic Surveyor	**Model**	Geodetic with ground plane
Part No.	18292-01	**Part No.**	14177-00
Serial No.	3610A14748	**Serial No.**	3017A00164
Firmware	7.29		

[5] The GeoGenius™ program was provided by Spectra Precision.

[6] The ESRI software is under licensure to Sonoma State University, Rohnert Park, CA

[7] Archaeologists seldom use total stations with a horizontal angular precision greater than 20 seconds. 20 seconds at 100 meters is approximately 1 cm. For this reason a separation of approximately 100 meters between the monuments has been deemed to be optimal.

Tripod and rover rod

Where possible fixed length rods stabilized by a bipod are used for the rover and the secondary reference receivers. The rod is plumbed carefully before beginning recording and checked at the end of the session. When the fixed length rod is used the antenna height is measured to the instrument height or Antenna Reference Point. In the case of the antennas used in this survey this point is at the base of the antenna. Where the fixed length rod could not be fixed in a stable manner over the monument, a slip-leg tripod is used, the antenna is leveled and plumbed over the mark, and the slope height of the antenna is measured at three points around the circumference of the ground plane before and after recording data.

ArchMapBZ layers

Landsat imagery

A landsat image of Belize forms the base layer of the ArchMapBZ GIS system. The image is a Landsat 5 image with an acquisition date of 27 December 1989. The sun is at an azimuth of 140.21° and an elevation of 38.76°. The pixel spacing in the image is 28.5 meters. The georeferencing for the image was corrected using data gathered mapping with GPS roads that are visible in the image.[8]

GPS Control Points

Data recording

Every effort has been made to design and implement a data recording protocol that meets the United States National Geodetic Survey User Densification Network standards and produces local accuracies of 1 cm horizontal and 2 cm vertical. The single exception to the NGS standards is the failure, for a number of reasons, to record meteorological data. These data are not currently used by GPS post-processing programs and it is unlikely that future programs will process them. There is little variability in the meteorological data during the course of the survey; it is hot, humid, clear to cloudy with fair to good visibility. It is not deemed a reasonable expenditure of human or other resources to record these data in the absence of clear reasons to do so.

A data recording session consists of both office and field components. The office component is composed of scheduling the field component using the planning software, operating the primary reference station, and the transfer to and postprocessing of the data on the computer.

With data being collected at the primary reference station a GPS control point field session consists of two observation periods of a minimum of thirty minutes each at two monumented control points and a contemporaneous observation at a temporary peripheral point used as a secondary reference station to improve the geometry of the session and to provide redundancy for the least squares network adjustment. Data is also being collected, of course, at the primary reference station during this period. The control point locations are selected according to the criteria listed above and a location is selected for the secondary reference station where GPS data reception is likely to be optimal.

Having determined the locations of the control points and the secondary reference point, and having placing monuments as necessary, the observations are conducted according to the following schedule.

1. The single frequency 4000SE receiver is placed at the secondary reference position and recording to a static file is begun.

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[8] The Landsat image was provided by Keith Clarke, Professor of Geography, University of California, Santa Barbara. The image is a part of the data base of the Geographic Information Center.

2. The dual frequency 4000SSE receiver is placed at one of the control points and recording to a fast static file is begun. This observation continues for a minimum of thirty minutes.
3. The 4000SSE receiver is moved to the other control point and observation at this point continues for a minimum of thirty minutes.
4. Steps two and three are repeated, again with minimum thirty-minute observations. Following the second of these repeated observations the fast static file on the 4000SSE is closed.
5. The static file on the 4000SE is closed.

ArchMapBZ control point network accuracy and precision

When used in the context of GPS mapping the term *accuracy* refers to the confidence with which the absolute location of the receiver is known and the term *precision* refers to the confidence with which the base line between the base station and the rover is known. Over the course of several years of research the present investigator has been unable to determine permanent reference monuments in Belize for which there is a high degree of confidence in the absolute location in the World Geodetic System 1984. There is a system of benchmarks established by the Interamerican Geodetic Survey in 1964 that provides a vertical control system.

Network accuracy

The network accuracy of the Archaeological Map of Belize was determined by a least squares adjustment of baselines between critical control points and the five closest Continuously Operating Reference Stations (CORS). These are located at Guatemala City, Tegucigalpa, San Lorenzo, San Salvador and Estili. The locations of the CORS stations are determined to the highest order of accuracy possible within the GPS system. The National Geodetic Survey (NGS) of the United States publishes the locations in both the NAD83 datum and the ITRF97 datum. The NAD83 datum locations do not change since the datum assumes that the North American plate does not move. The ITRF97 datum is an international datum and as such assumes and measures the changes in location based upon plate tectonics. The ITRF97 locations of the CORS stations include a date for the location and an annual velocity. For this study the ITRF97 locations of the five CORS stations were used with the location corrected to August 2001, the midpoint of the fieldwork. These CORS locations and the corrections are displayed in Appendix 1.

The network was first adjusted using only ArchMapBZ stations that had been occupied for significant lengths of time and were well positioned to provide a strong geometry and redundancy to the adjustment solution. The corrected locations of the five CORS stations were used as fixed horizontal and vertical control points. One of the stations occupied as a part of the ArchMapBZ survey is the Interamerican Geodetic Survey 1964 benchmark E10. Records in the office of Lands and Survey indicate an elevation of 231.7688 meters for this benchmark.[9] The initial network adjustment of the GPS survey, using only the five CORS stations as control points, determined an orthometric elevation of this station of 231.897 meters. Particularly given the length of time between the surveys and the significant change in technology, the relatively small twelve-centimeter difference between these surveys can be considered insignificant. The data were then adjusted again using the CORS stations as horizontal and vertical control points and the Interamerican Geodetic Survey benchmark E10, with the IGS 64 elevation assigned as

[9] These records were graciously made available to the investigators by Mr. Rolando A. Rosado, Principal Surveyor, Department of Lands and Survey, Government of Belize.

the orthometric elevation, as a vertical control point. The assignment of a local vertical control point along with the large number of long occupations at station TRS AS, the number of moderately long occupations at other stations in the network, the redundancy due to simultaneous occupations and the use of precise ephemeredes produced a high degree of accuracy for the network, particularly within the Belize Valley itself. The five CORS control points, the Interamerican Geodetic Survey horizontal control point and the thirty-five other points in the network are connected by 244 baselines providing a high degree of redundancy. At the two sigma (95%) level of confidence the standard error of unit weight in the network is 0.386. The accuracy of the critical control points within the Belize Valley at Baking Pot and nearby at El Pilar falls within the Federal Geographic Data Committee 5-centimeter classification. (FGDC 1998a Table 2-1, Accuracy Standards, pp. 2f.) The critical points at Caracol and Lamanai have significantly longer baselines from the station at TRS AS and consequently have a lesser accuracy. Since this least squares adjustment is constrained by fixing the locations of the CORS reference points, it is said to be a biased adjustment. The degree of error in this adjustment is displayed in the table below. The postprocessing program. *GeoGenius*, reports the adjustment error as error ellipses. The FGDC classification is based on a 95% Confidence Error Circle. This figure is computed as the mean between the two values of the error ellipse. (FGDC 1998b, pp. 3-6) It is this figure that is the basis for the assignment of the accuracy of a station to an FGDC horizontal classification. The vertical classification is based upon the height error reported. Future propagation of the control point network will begin with ties to the three points that fall within the 5-Centimeter classification, the first three points in the table below.

Network accuracy, adjustment biased by CORS

		2 sigma error. mm			mm.		
Station	**Site**	**North**	**East**	**Height**	**95% circle**	**H Class**	**V Class**
1001	Cahal Pech	37.5	19.5	21.8	28.5	5-Centimeter	5-Centimeter
1002	Cahal Pech	37.4	19.4	21.7	28.4	5-Centimeter	5-Centimeter
1003	Baking Pot	32.7	23.2	24.2	28.0	5-Centimeter	5-Centimeter
1004	Baking Pot	42.9	28.0	29.8	35.5	5-Centimeter	5-Centimeter
1005	Xunantunich	52.5	38.4	39.9	45.5	5-Centimeter	5-Centimeter
1006	Xunantunich	52.3	38.2	39.8	45.3	5-Centimeter	5-Centimeter
1007	Caracol	94.9	83.7	84.8	89.3	1-Decimeter	1-Decimeter
1008	Caracol	94.9	83.7	84.8	89.3	1-Decimeter	1-Decimeter
1011	El Pilar	44.4	26.4	28.6	35.4	5-Centimeter	5-Centimeter
1012	El Pilar	44.6	26.6	28.8	35.6	5-Centimeter	5-Centimeter
1013	Lamanai	168.5	158.7	159.7	163.6	2-Decimeter	2-Decimeter
1014	Lamanai	168.5	158.7	159.8	163.6	2-Decimeter	2-Decimeter
1015	Lamanai	168.7	158.8	159.9	163.8	2-Decimeter	2-Decimeter
4001	Xunantunich	37.4	19.3	21.7	28.4	5-Centimeter	5-Centimeter
4005	Caracol	94.8	83.6	84.7	89.2	1-Decimeter	1-Decimeter

4006	Caracol	94.7	83.6	84.7	89.2	1-Decimeter	1-Decimeter
9001	Xunantunich	43.3	25.3	27.5	34.3	5-Centimeter	5-Centimeter
EPB1	El Pilar	87.3	69.9	71.7	78.6	1-Decimeter	1-Decimeter
PH06	Pook's Hill	123.6	106.2	108.0	114.9	2-Decimeter	2-Decimeter
PH08	Pook's Hill	123.7	106.3	108.0	115.0	2-Decimeter	2-Decimeter
PH21	Pook's Hill	123.7	106.2	108.0	115.0	2-Decimeter	2-Decimeter
TRS_ BP191	Baking Pot	36.7	24.8	26.2	30.8	5-Centimeter	5-Centimeter
TRS_ CR197	Caracol	90.3	82.2	83.0	86.3	1-Decimeter	1-Decimeter
TRS_ EP205	El Pilar	31.3	18.3	19.9	24.8	5-Centimeter	2-Centimeter
TRS_ LM204	Lamanai	166.5	158.1	159.0	162.3	2-Decimeter	2-Decimeter
TRS_ XU192	Xunantunich	64.4	43.0	45.4	53.7	1-Decimeter	5-Centimeter
TRS_ XU193	Xunantunich	48.9	36.8	38.1	42.9	5-Centimeter	5-Centimeter

These data are within the Network Accuracy Standards minimally acceptable levels of differential relative positional accuracy required of a United States Government cadastral survey. All of the data except that from Lamanai and Pook's Hill falls within the highest standard. Data with a 95% Confidence Circle less than 10 centimeters qualify for the *Cadastral Project Control* designation. The data from Lamanai and Pook's Hill, with a 95% Confidence Circle less than 20 centimeters qualify for the application *Cadastral Measurement* designation. (USDA, *et al.* 2000, p.6)

Local accuracy, adjustment biased by previously fixed control points

The ArchMapBZ stations in the table above were selected for their utility in determining the absolute location of the control points in the WGS84 system. The following table displays all of the control points in the network with errors by axis, the 95% Confidence Error Circle and the resulting FGDC classification. The least squares adjustment process that produced the data from which this table was constructed was constrained by fixing TRS AS as a horizontal and vertical control point. In the cases of Lamanai and Caracol, since the base line with TRS AS is so long. The secondary reference station on those sites was also fixed as a control point with the values determined in the network adjustment above.

Station	**Site**	**2 sigma error, mm.**			**95% circle**	**FGDC**	
		North	**East**	**Height**	**mm.**	**H Class**	**V Class**
1004	Baking Pot	1.4	1.4	3.8	1.4	2-Millimeter	5-Millimeter
1003	Baking Pot	1.6	1.5	4.2	1.55	2-Millimeter	5-Millimeter
1002	Cahal Pech	8.4	7.7	24.7	8.05	1-Centimeter	5-Centimeter

1001	Cahal Pech	11.2	11.2	27.7	11.2	2-Centimeter	5-Centimeter
EPB1	El Pilar	21.6	21.6	58.6	21.6	5-Centimeter	1-Decimeter
1006	Xunantunich	28.1	15.7	17.3	21.9	5-Centimeter	2-Centimeter
1011	El Pilar	25.8	24.4	90	25.1	5-Centimeter	1-Decimeter
IGS E10	El Pilar	22.3	32.2	135	27.25	5-Centimeter	2-Decimeter
4001	Xunantunich	42	23.9	26.2	32.95	5-Centimeter	5-Centimeter
9116	Xunantunich	42.4	24.3	26.5	33.35	5-Centimeter	5-Centimeter
1005	Xunantunich	45.9	26.9	29.2	36.4	5-Centimeter	5-Centimeter
1007	Caracol	47.1	47.2	158.1	47.15	5-Centimeter	2-Decimeter
1012	El Pilar	31.2	65.9	170.3	48.55	5-Centimeter	2-Decimeter
1008	Caracol	65.5	61.4	193.1	63.45	1-Decimeter	2-Decimeter
4005	Caracol	67.9	74.1	362.4	71	1-Decimeter	5-Decimeter
4006	Caracol	99.4	83.4	303.3	91.4	1-Decimeter	5-Decimeter
1015	Lamanai	111.6	142.4	428.4	127	2-Decimeter	5-Decimeter
1013	Lamanai	138.1	147.4	375.5	142.75	2-Decimeter	5-Decimeter
1014	Lamanai	334.1	438.7	1008.7	386.4	5-Decimeter	2-Meter

With the exception of the data from Lamanai, these data are within the Local Accuracy Standards minimally acceptable levels of differential relative positional accuracy required of a United States Government cadastral survey. The data from Caracol, with a 95% Confidence Circle less than 10 centimeters qualify for the *Cadastral Measurement* designation. All of the other data with a 95% Confidence Circle less than 5 centimeters qualify for the *Cadastral Project Control* designation. (USDA, *et al.* 2000, p.6)

GPS Reference Points

GPS reference points have less demanding data collection procedures than those for GPS control points. The process is similar to that with control points without the redundancy. The reference point is occupied for a single occupation of at least twenty minutes. A secondary reference station is used so that there is sufficient redundancy to apply least-squares adjustment. These techniques have been used to record locations of permanent monuments that will not be used in the future as a reference position in the propagation of the control point network. Two monuments in the plazeula group at Pook's Hill as well as a number of monuments at the El Pilar Archaeological Reserve were recorded by these methods. The monuments at El Pilar include the reserve boundary monuments on the Belizean side of he reserve as well as two monuments that are a part of the original British demarcation of the border with Guatemala.

Topography

Accurate and rapidly gathered data for topography is possible through the OTF (on-the-fly) initialization capabilities of the dual frequency rover receiver. The precision of the points in the kinematic file is a function of the total length of time that the receiver is recording with uninterrupted signal from a minimum of five satellites. At the site of Baking Pot topographic data was gathered on mounds on foot with the GPS antenna mounted on a rover pole and over a large part of the residential part of the site by using a magnetic antenna mount on the roof of a four-wheel-drive vehicle. Points were gathered at the rate of one every five seconds. The postprocessed 95% precision is approximately 0.5 cm. horizontal and 2.5 cm. Vertical. The worst vertical precision in over 2,700 points collected is 7.5 cm. Contour maps with a 0.5 meter or less contour interval can be constructed with confidence in this way.

Georeferenced imagery

A series of low platforms formed by stone walls with cobbled fill was a principal feature of a group excavated in the Summer 2001 season of BVAR under the supervision of Carolyn Audet of Vanderbilt University. String and tape were strung between nails driven into the tops of these walls in the same manner as when preparing to do a plan of a wall top using a baseline and offset mapping technique. The nail points were located using the GPS reference point protocol. Photos were taken of the wall top approximately every half-meter with a hand held digital camera. Excel™ was used to create an ArcView™ feature marking the half-meter intervals along the string and tape line between the nail points on the wall line. The interval markings are clearly visible in the photographs. The Image Analysis™ extension of ArcView™ was used first to georeference and then to mosaic the wall images. In this manner features at the unit level can be incorporated into the same mapping system that is used at the regional and the national scale.

Soil maps

Additional material continues to be added to the GIS as it becomes available. Included in C. J. Birchall and R. N. Jenkin, *The Soils of the Belize Valley, Belize,* are a series of soil maps based upon the 1:50,000 map series. Personnel of the GIS Office of Sonoma County scanned the maps at 300 dpi with their large capacity scanner. These images were georeferenced using Image Analysis™ and incorporated as a layer in the GIS.

Expansion of the GIS

During the 2002 season of the Belize Valley Archaeological Reconnaissance Project the principal focus for expansion of the GIS will be to incorporate additional sites into the control point network. Some of these sites will be from among a group chosen by the Department of Archaeology of Belize for evaluation. Other sites will be included at the request of archaeologists investigating the site.

It is the intent of the investigator to make the coordinate values of the control point network available through the Internet. At this point all of the sites in the system are well known to investigators. As the locations of lesser-known sites begin to be incorporated into the GIS, information will be selectively released through a protocol being developed with the Department of Archaeology.

Appendix 1: CORS locations

Antenna Reference Point(ARP): **GUATEMALA CITY CORS ARP**											ITRF97	D
ITRF97 POSITION (EPOCH 1997.0)											Computed for	
Computed in Aug., 2000.000 using 13.000 days of data.									|	12	August 2001	mm.
X	=	-56063.621	m	latitude	=	14	35	25.454	N	12	-56063.618	0.003
Y	=	-6174978.673	m	longitude	=	90	31	12.660	W	12	-6174978.673	0.000
Z	=	1596665.233	m	HAE	=	1519.868		m	|	12	1596665.232	-0.001
|												
ITRF97 VELOCITY												
Predicted with HTDP_2.4 in Aug., 2000												
VX	=	0.004	m/yr	north	=	-0.001	m/yr	|				
VY	=	0.000	m/yr	east	=	0.004	m/yr	|				
VZ	=	-0.001	m/yr	east	=	0.000	m/yr	|				
|												
Antenna Reference Point(ARP): **TEGUCIGALPA CORS ARP** |												
Computed in June, 2000.000 using 11.000 days of data.									|	14		
X	=	301697.346	m	latitude	=	14	5	25.581	N	14	301697.351	0.005
Y	=	-6181025.110	m	longitude	=	87	12	20.148	W	14	-6181025.109	0.001
Z	=	1542919.832	m	HAE	=	948.825		m	|	14	1542919.834	0.002
|												
ITRF97 VELOCITY |												
Velocities computed using the model in XSITES May, 2000.000									|			
VX	=	0.005	m/yr	north	=	0.002	m/yr	|				
VY	=	0.001	m/yr	east	=	0.005	m/yr	|				
VZ	=	0.002	m/yr	east	=	0.000	m/yr	|				
|												

Antenna Reference Point(ARP): **SAN SALVADOR CORS ARP** |												
PID	=	AI8353	|									
|												
ITRF97 POSITION (EPOCH 1997.0) |												
Computed in Apr., 2001.000 using 32.000 days of data.									|	4		
X	=	95566.964	m	latitude	=	13	41	49.504	N	4	95566.965	0.001
Y	=	-6197785.598	m	longitude	=	89	6	59.745	W	4	-6197785.598	0.000
Z	=	1500590.479	m	HAE	=	626.631		m	|	4	1500590.479	0.000
|												
ITRF97 VELOCITY |												
Predicted with HTDP_2.4 in Oct., 2000.000 |												
VX	=	0.004	m/yr	north	=	0.000	m/yr	|				
VY	=	0.000	m/yr	east	=	0.004	m/yr	|				
VZ	=	0.000	m/yr	east	=	0.000	m/yr	|				
Antenna Reference Point(ARP): **SAN LORENZO CORS ARP** |												
ITRF97 POSITION (EPOCH 1997.0) |												
Computed in Jan., 2001.000 using 17.000 days of data.									|	7		
X	=	277528.923	m	latitude	=	13	25	26.105	N	7	277528.925	0.002
Y	=	-6198801.814	m	longitude	=	87	26	11.402	W	7	-6198801.814	0.000
Z	=	1471065.567	m	HAE	=	11.995		m	|	7	1471065.567	0.000
ITRF97 VELOCITY |												
Predicted with HTDP_2.4 in Jan., 2001.000 |												
VX	=	0.004	m/yr	north	=	0.000	m/yr	|				
VY	=	-0.001	m/yr	east	=	0.004	m/yr	|				
VZ	=	0.000	m/yr	east	=	0.001	m/yr	|				
Antenna Reference Point(ARP): **ESTELI NICARAGUA CORS ARP**												
Computed in June, 2000.000 using 13.000 days of data.									|	14		
X	=	394283.471	m	latitude	=	13	5	58.327	N	14	394283.477	0.006
Y	=	-6201541.433	m	longitude	=	86	21	43.661	W	14	-6201541.432	0.001
Z	=	1436325.757	m	HAE	=	852.670		m	|	14	1436325.760	0.003
|												
ITRF97 VELOCITY |												
Predicted with HTDP_2.3 in June, 2000.000 |												
VX	=	0.005	m/yr	north	=	0.003	m/yr	|				
VY	=	0.001	m/yr	east	=	0.005	m/yr	|				
VZ	=	0.002	m/yr	east	=	0.000	m/yr	|				

Appendix 2: ArchMapBZ control point coordinate values

Control point descriptions

Station	Site	Local ID	Type	Monument
1001	Cahal Pech	1001	Primary	Nail, aluminum label
1002	Cahal Pech	1002	Secondary	Nail, aluminum label
1003	Baking Pot	1003	Primary	BVAR Concrete monument
1007	Caracol	1007	Primary	Nail, aluminum label
1008	Caracol	1008	Secondary	Nail, aluminum label
1009	Blackmun Eddy	1009	Secondary	Concrete property monument
1010	Blackmun Eddy	1010	Primary	BVAR Concrete monument
1011	El Pilar	C5	Primary	BVAR Concrete monument
1012	El Pilar	C6	Secondary	BVAR Concrete monument
1013	Lamanai	1013	Primary	Existing concrete monument
1014	Lamanai	1014	Secondary	Existing concrete monument
1015	Lamanai	1015	Secondary	Existing concrete monument
4001	Xunantunich	4001	Reference	Existing nail in consolidated material
4005	Caracol	4005	Reference	Nail, aluminum label
4006	Caracol	4006	Reference	Nail, aluminum label
9116	Xunantunich	91_16	Reference	Existing concrete monument
1004	Baking Pot	1004	Secondary	BVAR Concrete monument
1005	Xunantunich	1005	Primary	Nail, aluminum label
1006	Xunantunich	1006	Secondary	Nail, aluminum label
EPB1	El Pilar	EPB1	Secondary	BVAR Concrete monument
IGS E10	El Pilar	IGS_E10	Reference	IGS Benchmark

Control Point WGS84 coordinates

Station	WGS84 X	WGS84 Y	WGS84 Z
1001	98508.922	-6095830.848	1868298.274
1002	98527.515	-6095814.543	1868321.660
1003	105366.062	-6093793.883	1874067.534
1007	94076.125	-6108571.800	1827970.582
1008	94025.486	-6108582.149	1827853.994
1011	90861.923	-6092515.472	1879585.349
1012	90865.903	-6092486.251	1879678.625
1013	142857.223	-6074203.072	1933713.722
1014	142868.829	-6074204.640	1933707.086
1015	143160.831	-6074067.356	1934115.155
4001	91315.516	-6097729.112	1862472.114
4005	93718.586	-6108603.246	1827851.187
4006	93758.801	-6108617.548	1827797.198
9116	91312.443	-6097767.410	1862338.956
1004	105398.265	-6093831.729	1873936.044
1005	91353.597	-6097813.369	1862309.619
1006	91305.377	-6097720.421	1862524.439
EPB1	91057.536	-6092649.808	1879154.236
IGS E10	91045.837	-6092561.770	1879395.529

Control Point UTM coordinates, latitude and longitude

Station	UTM 16N					
	Northing	Easting	HAE	Ortho. Ht.	Latitude	Longitude
1001	1896848.837	279348.974	179.391	183.480	N 17°08'44.44972"	W 89°04'27.04083"
1002	1896875.703	279368.120	170.994	175.085	N 17°08'45.33005"	W 89°04'26.40295"
1003	1902856.510	286303.981	46.505	50.821	N 17°12'02.20640"	W 89°00'33.88909"
1007	1854624.403	274264.057	537.953	540.494	N 16°45'49.51996"	W 89°07'03.63401"
1008	1854510.541	274212.040	513.489	516.026	N 16°45'45.79904"	W 89°07'05.34887"
1011	1908730.816	271881.946	236.651	241.239	N 17°15'08.20106"	W 89°08'44.05743"
1012	1908828.509	271887.448	236.469	241.060	N 17°15'11.37987"	W 89°08'43.90796"
1013	1965039.667	324788.472	13.242	19.384	N 17°45'56.67093"	W 88°39'09.81867"
1014	1965032.684	324799.977	12.969	19.111	N 17°45'56.44712"	W 88°39'09.42602"
1015	1965458.451	325098.879	13.341	19.490	N 17°46'10.38125"	W 88°38'59.40607"
4001	1890832.494	272059.875	171.441	175.363	N 17°05'26.23087"	W 89°08'31.34698"
4005	1854506.408	273904.745	528.363	530.902	N 16°45'45.55797"	W 89°07'15.72027"
4006	1854449.978	273944.141	527.076	529.613	N 16°45'43.73652"	W 89°07'14.37009"
9116	1890693.995	272054.705	168.868	172.785	N 17°05'21.72513"	W 89°08'31.47032"
1004	1902719.205	286334.107	44.303	48.614	N 17°11'57.75116"	W 89°00'32.82155"
1005	1890651.817	272094.714	204.762	208.678	N 17°05'20.36784"	W 89°08'30.10181"
1006	1890885.225	272050.444	178.368	182.292	N 17°05'27.94225"	W 89°08'31.68548"
EPB1	1908276.182	272070.534	239.875	244.447	N 17°14'53.48508"	W 89°08'37.50431"
IGS E10	1908532.929	272062.999	227.189	231.769	N 17°15'01.83142"	W 89°08'37.85576"

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