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ESTABLISHMENT OF THIRD ORDER CONTROLS WITH DIFFERENTIAL GLOBAL POSITIONING SYSTEM (DGPS) WITHIN UNIVERSITY OF MAIDUGURI

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ABSTRACT

This research aimed at establishing both vertical and horizontal controls within the University of Maiduguri. The provision of such control network will help in conducting accurate surveying work as it will serve as reference station with known coordinates (easting, northing and height).Three coordinates of second order control stations were collected from Borno Geographic Information Service (BOGIS): BSC 008, BSC 009 and BSC 010 respectively and were used as reference stations. With the help of Google earth imagery, the actual location of these controls was identified on the ground and suitable stations for the controls were established. Twelve set of controls were established and numbered as GMT 001 to GMT 012. Differential Global Positioning System (High target) was used for the observation on the controls and their coordinates were given in real time after been subjected to least square adjustment as a standard goal data for control establishment.

Keywords: Establishment of Controls, Differential Global Positioning System (DGPS), Data Processing, Controls points, monumentation,

INTRODUCTION

The importance of geodetic controls to Geodesy, Surveying, Mapping and Engineering cannot be over emphasized. Among other functions, controls help in the maintenance of uniform coordinates within the country. Ono *et. al.* (2013) showed that the greatest challenge to the existence and sustainability of these controls in Nigeria is that these controls are destroyed during engineering works like buildings, road construction and other infrastructural developments. Geodetic control network is a geometric configuration of three or more terrestrial survey points that are connected either by geodetic measurements made among them or by astronomical or space techniques. Developments necessitate the need for a network of appropriately distributed points of known horizontal and vertical coordinates. These includes: boundary demarcation, urban management, hydrographic, environmental management, ecology, earthquake-hazard assessment, space research, geophysics, aerial photography and deformation monitoring. Repeated geodetic measurements on a network of points have been used to monitor and predict crustal movements, slope creep studies, ground subsidence, and the deformation of man-made structures such as water power dams, underground tunnels, bridges (Tzouvaras, M. (2020).

The quality (accuracy) of geodetic control directly affects results obtained, so it is very important to analyze the accuracy of established geodetic network before it can be used as the base for displacements and deformations determination. Geodetic control densification can be achieved by both conventional and GPS surveying methods for a high-order geodetic control densification (John 2015). The main elements for established geodetic control accuracy are its precision and reliability. It has been prescribed that the First-order network has got minimum distance accuracy 1:100 000. Distance accuracy is the ratio of the relative positional error of a pair of control points to the horizontal separation of those points. The same concept was valid for vertical networks. The accuracy standards have been referring to the accuracy in determining height differences (not to the bench mark heights) and they have been proportional to distance: for differential levelling directly proportional to square root of distance, and for trigonometric levelling directly proportional to distance between points. Then second order control (secondary control) with an accuracy of 1:50,000 suitable for subsidiary metropolitan control. Lastly third order control (local control) with an accuracy of 1:10,000 which is use for plane surveying such as cadastral for certificate of occupancy.

Control points are usually established as reference points which positions are well defined (monumented) in the ground and whose coordinates system are known. A horizontal datum (control) use to define latitude and longitude (northing and easting) locations, while a vertical datum used to define elevations or depths. It is a specific point on the earth surface with known height in relation to mean sea level. The research aim to establish a third order control points within University of Maiduguri using differential global positioning system, with the objectives of network design, monumentation, execution (field observation) and network analysis. Network analysis deals with the processing and analysis of the collected geodetic data and reporting the network results together with their quality.

STATEMENT OF PROBLEM

Control points are required to ensure strong network geometry for the users of the control and to provide several closure checks to help measure accuracy (Vashada, et al. (2019). Lack of such control within the study area (UNIMAID) has hindered the achievement of high accurate survey work. It prevents quality research work in the field of Geomatics, Civil engineering and other related environmental professions, connecting the work with controls located outside the University makes it more difficult and expensive, hence this research established a third order controls (local controls) across the university with differential GPS to remedy the difficulties faced in conducting survey training/projects.

LITERATURE

Olatunde, M. B. *et al.* (2022) conducted a research in Iyakpi city Auchi in Edo State Nigeria, established Second Order control points using Global Navigation Satellite System (GNSS) technology and five control pillars were established according to specification with GPS observation in static mode in all the stations. The data obtained was downloaded and processed with Leica Geo Office Software. Geographic Information System (GIS) database was created to help manage the spatial and non-spatial data. The list of adjusted coordinates of five control points was generated together with the map showing the spatial distribution of the control points around the study area. It was recommended that there should be frequent database update and the controls should be densified. In terms of observation, static mode was used which needs further processing, hence, real time kinematic should be adopted since the controls were in Second Order instead of Third Order.

Similarly, Takana A. *et al.* (2017) in a journal titled "Establishment of Geodetic Controls Network for Monitoring of Jimeta Bridge" in Adamawa State, Nigeria, used Differential Global Positioning System (GPS) receivers with capabilities of accurate long-term to establish a geodetic control network within the study area to monitor the monuments on the bridge. Least squares were used to the observation and adjustment as standard goal data for deformation monitoring network was obtained to determine the vector of structural deformation of Jimeta Bridge. The data obtained was downloaded and processed using GNSS solutions. Least squares adjustment was used at two different stages in processing GPS carrier-phase measurements.

STUDY AREA

The study area is located between latitude 11^0 49' 7.68'' N and 11^0 47' 49.92'' N and longitude 13^0 11' 12.48''E and 13^0 12' 43.2''E with average height of about 350m above sea level, situated along Bama road in Jere Local Government Area of Borno state. The inhabitants of university of Maiduguri are basically composed of staff and students with staff quarters, student's hostels, religious monuments, sporting and clinic etc. It has the total area of approximately 4131.07 hectares. The Satellite image and map of the study area is shown in Figure 1.

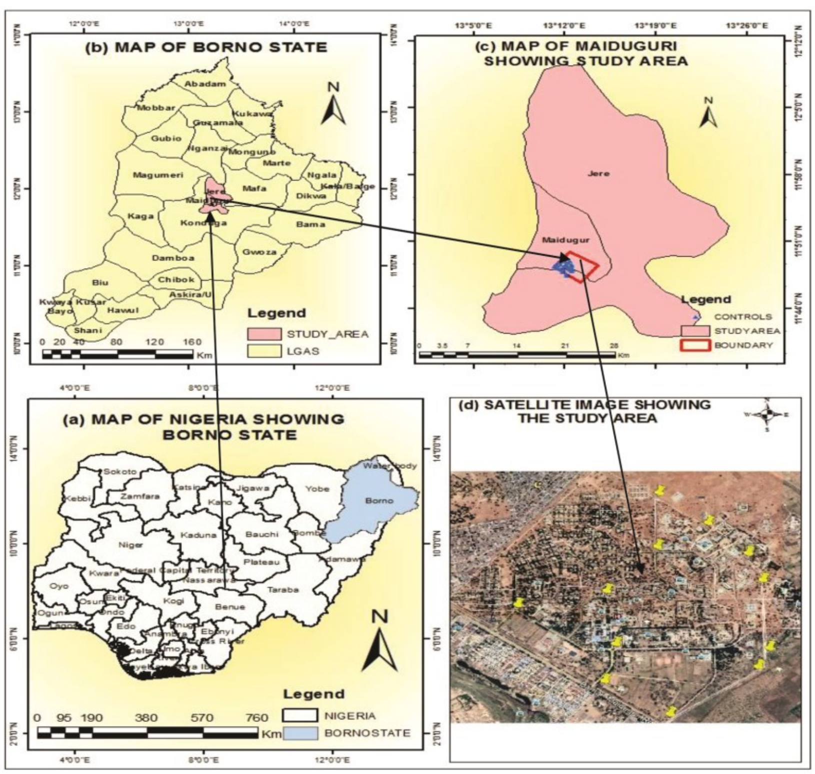


Figure 1: Satellite image and map of the study area, source (A. peter *et al.* 2024)

METHODOLOGY

Data Acquisition

The acquired data for the research passed through many stages which includes; Recconnissance, Field observation, Data processing, Analysis and presentation of results. The coordinates of second order controls sited close to the study area were obtained from Borno Geographic Information Services (BOGIS) as shown in Table 1, which are in are Cartesian coordinate system, and were subjected to check as shown in Table 2.

Table 1; Cartesian coordinate system

Stations	Detailed	Easting (m)	Northing (m)	Height(m)
BS08	ST-Patrick	297644.462	1309188.081	321.165
BS09	Polo Ground	298281.669	1305596.165	331.958
BS10	NUJ	301262.989	1307220.52	324.641

Control check

Control checks are necessary where a surveying work is to be tied to reference points. This is to ascertain whether the control pillars coordinates of second order controls sited close to the study area were obtained are in-situ or not. From the check carried out it shows that the control pillars are *in-situ*. Table 2 shows the level of satisfaction to which the work had been carried out.

Table 2: Control check data table

Name	Description	ExistingE(m)	Observed E(m)	Diff. (m)	Existing N(m)	Observed N(m)	Diff. (m)	Rmk
BS08	ST-Prysch	297644.462	297644.441	0.021	1309188.083	1309188.081	0.002	OK
BS09	Polo Ground	298281.669	298281.666	0.003	1305596.165	1305596.164	0.001	OK
BS10	NUJ	301262.989	301262.987	0.002	1307220.517	1307220.514	0.003	OK

Data Collection

Basically in this research, Hi-Target V90 differential GPS was used in real time kinematic method, to carry out the observations on the stable ground monuments serving as the control point network. The static mode was used to observe both control networks on the stable ground and one of the controls obtained from BOGIS (BSC 008) was used as a base station, which remained stationary on the control station and all the necessary settings were made. The rover was set on the control point (GMT 001), the time elapse was set to one hour and the coordinates, height and other parameters were recorded and saved automatically by the receiver. The same processes were repeated on GMT 002, GMT 003, GMT 004, until the coordinates (Real time) of entire monumented controls (GMT 001 to GMT 012) within the study area were recorded respectively.

Data Processing

The data obtained from the field using GPS observation for the control networks were processed and Adjustment using Hi-Target Business Center (HBC) which offers high standards of performance, processing speed, compactness and flexibility. It provides accurately determined final result based on least squares solution. Least squares adjustment was used at two different stages in processing GPS carrier-phase measurements. First, it is applied in the adjustment that yields baseline components between stations from the redundant carrier-phase observations and secondly, it is employed in processing GPS observations for adjusting baseline vector components in the network. In network adjustments, the goal is to make all X-coordinates and all Y-coordinate differences consistent throughout the points. The three COR Stations, ZRKD at ABU Zaria; CBCR in Calabar and ABFC is the COR Station in Abuja specifically in OSGoF were also used as the Controls from where the observed stations were coordinated using LEICA Geo Office 8.4 application software as shown in Figure 2 and also the Network baseline connections is shown in figure 3.

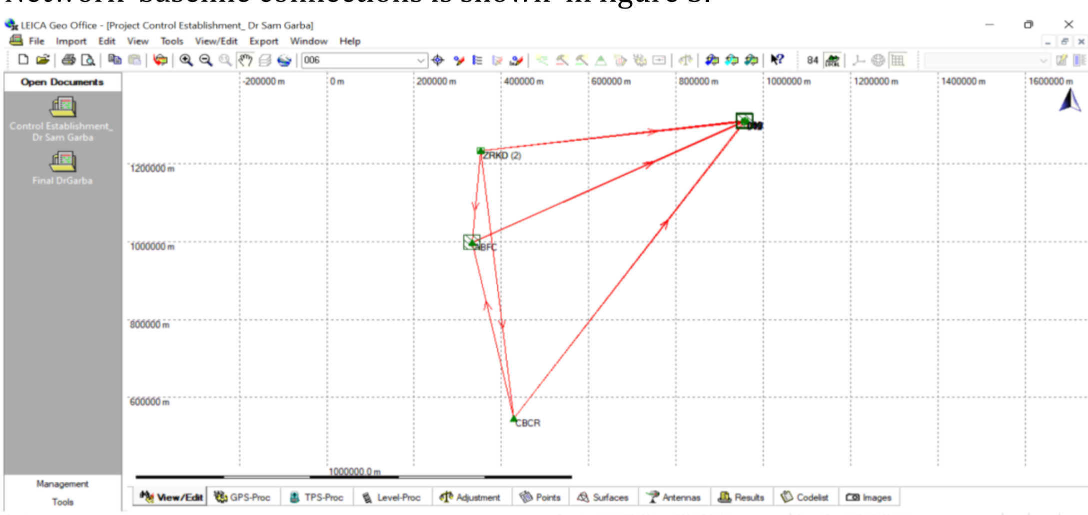


Figure 2: Connection to the Nigerian CORS Station, source Author

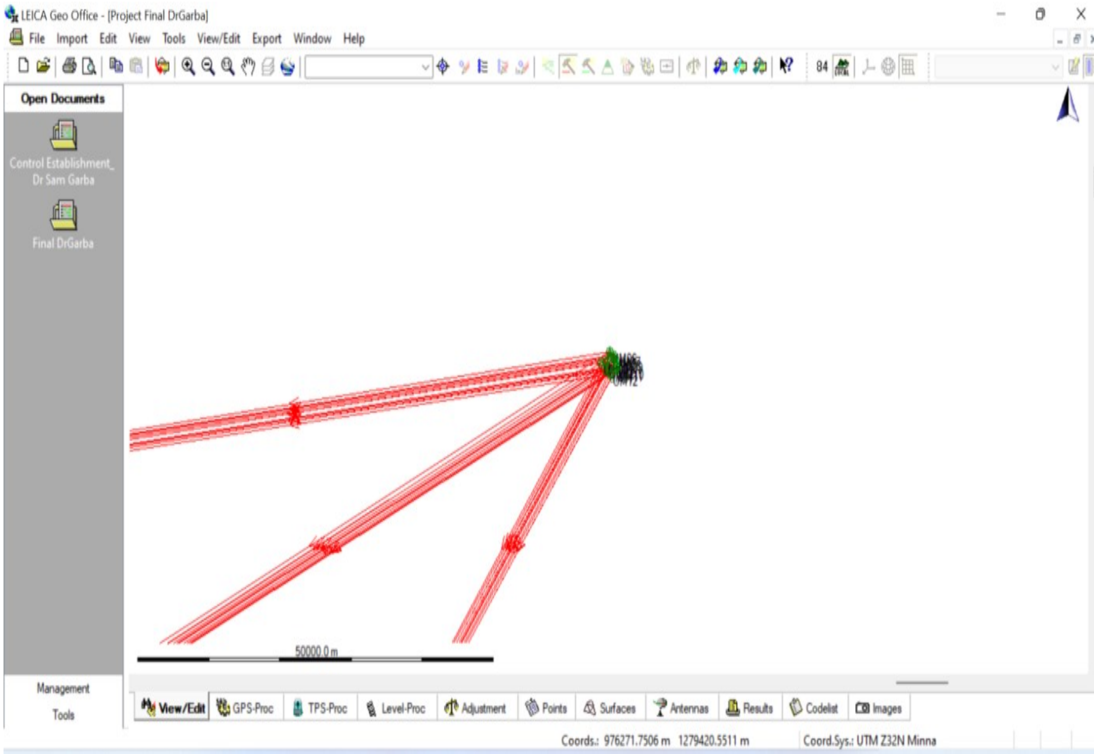


Figure 3: Control Network showing the baseline connections, source Author

RESULTS AND DISCUSSIONS

The result of the control network processed from one of the controls obtained from BOGIS (BSC 008) is shown in Table 3,while the adjustment results obtained by using the COR Stations are represented in Tables 4, and Figure 4 . The analysis of the control networks with degrees of freedom as 87 and with some testing; Alfa (multi dimensional): 0.6131
Alfa 0 (one dimensional): 5.0 %, Beta: 80.0 %, Sigma a-priori (GPS): 10.0, Critical value W-test: 1.96, Critical value T-test (2-dimensional): 2.42, Critical value T-test (3-dimensional): 1.89, Critical value F-test: 0.95

Table 3: The processed results from BOGIS (BSC 008) control

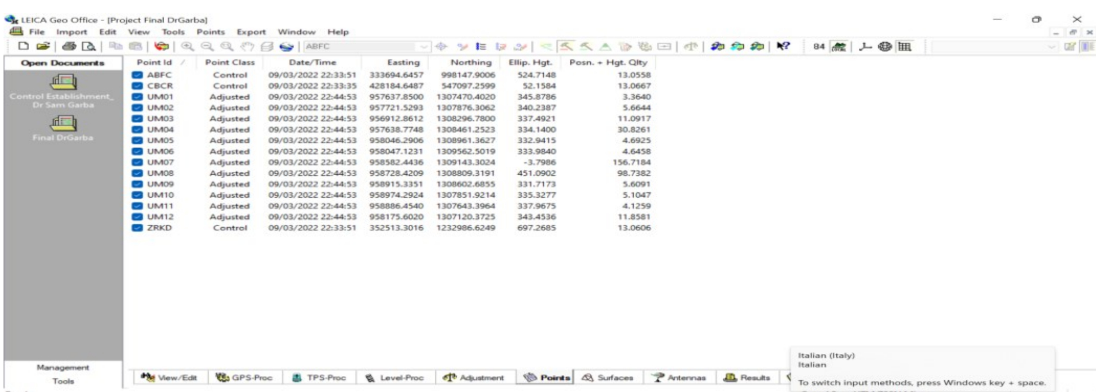
Station	Easting(m)	Northing(m)	Height(m)
GMT 001	1304415.683	304047.616	329.186
GMT 002	1304925.165	304768.005	338.130
GMT 003	1305130.748	304859.012	336.957
GMT 004	1305881.144	304815.753	334.168

Station	Easting(m)	Northing(m)	Height(m)
GMT 005	1306178.709	304697.738	334.460
GMT 006	1306518.366	304373.890	319.074
GMT 007	1306857.926	303970.461	322.643
GMT 008	1306256.781	303956.169	320.872
GMT 009	1305768.085	303539.757	338.510
GMT 010	1305618.009	302810.721	327.001
GMT 011	1305183.276	303609.591	340.286
GMT 012	1304780.345	303518.493	344.090

Table 4: Adjusted Coordinates (Results) from CORS staions in Eastings and Northings

Station		Coordinate(m)	Corr	Sd	
ABFC	Easting	333694.646	0.0000	0.0001	fixed
	Northing	998147.901	0.0000	0.0003	fixed
	Height	524.715	0.0000	0.0012	fixed
CBCR	Easting	428184.649	0.0000	0.0001	fixed
	Northing	547097.26	0.0000	0.0004	fixed
	Height	52.158	0.0000	0.0012	fixed
GMT01	Easting	957637.85	-0.0006	1.1828	
	Northing	1307470.402	0.0001	1.1168	
	Height	345.879	0.0000	2.9445	
GMT02	Easting	957721.53	-0.0006	2.3013	
	Northing	1307876.306	0.0001	1.3582	
	Height	340.239	0.0000	4.9945	
GMT03	Easting	956912.861	-0.0006	3.7145	
	Northing	1308296.78	0.0001	2.8335	
	Height	337.4921	0.0000	10.0598	
GMT04	Easting	957638.775	-0.0006	11.0065	
	Northing	1308461.252	0.0001	7.6851	
	Height	334.14	0.0000	27.7496	
GMT05	Easting	958046.291	-0.0006	1.7204	
	Northing	1308961.363	0.0001	1.5573	
	Height	332.942	0.0000	4.0786	

Station		Coordinate(m)	Corr	Sd	
GMT06	Easting	958047.123	-0.0006	1.8095	
	Northing	1309562.502	0.0001	1.242	
	Height	333.984	0.0000	4.0947	
GMT07	Easting	958582.444	-0.0006	21.6806	
	Northing	1309143.302	0.0001	29.3036	
	Height	-3.799	0.0000	152.4202	
GMT08	Easting	958728.421	-0.0006	32.7955	
	Northing	1308809.319	0.0001	40.2197	
	Height	451.09	0.0000	84.0004	
GMT09	Easting	958915.335	-0.0006	1.9597	
	Northing	1308602.686	0.0001	1.7607	
	Height	331.717	0.0000	4.952	
GMT10	Easting	958974.292	-0.0006	1.6392	
	Northing	1307851.921	0.0001	1.2985	
	Height	335.328	0.0000	4.6567	
GMT11	Easting	958886.454	-0.0006	1.5323	
	Northing	1307643.396	0.0001	1.2619	
GMT12	Easting	958175.602	-0.0006	5.9806	
	Northing	1307120.373	0.0001	4.6733	
	Height	343.454	0.0000	9.1108	
ZRKD	Easting	352513.302	0.0000	0.0001	fixed
	Northing	1232986.625	0.0000	0.0003	fixed
	Height	697.269	0.0000	0.0012	fixed


LEICA Geo Office - [Project Final DrGarba]

Point Id	Point Class	Date/Time	Easting	Northing	Ellip. Hgt.	Posn. + Hgt. Qlty
ABFC	Control	09/03/2022 22:33:51	333694.6457	998147.9006	524.7148	13.0558
CBCR	Control	09/03/2022 22:33:35	428184.6487	547097.2599	52.1584	13.0667
UM01	Adjusted	09/03/2022 22:44:53	957637.8500	1307470.4020	345.8786	3.3640
UM02	Adjusted	09/03/2022 22:44:53	957721.5293	1307876.3062	340.2387	5.6644
UM03	Adjusted	09/03/2022 22:44:53	956912.8612	1308296.7800	337.4921	11.0917
UM04	Adjusted	09/03/2022 22:44:53	957638.7748	1308461.2523	334.1400	30.8261
UM05	Adjusted	09/03/2022 22:44:53	958046.2906	1308961.3627	332.9415	4.6925
UM06	Adjusted	09/03/2022 22:44:53	958047.1231	1309562.5019	333.9840	4.6458
UM07	Adjusted	09/03/2022 22:44:53	958582.4436	1309143.3024	-3.7986	156.7184
UM08	Adjusted	09/03/2022 22:44:53	958728.4209	1308809.3191	451.0902	98.7382
UM09	Adjusted	09/03/2022 22:44:53	958915.3351	1308602.6855	331.7173	5.6091
UM10	Adjusted	09/03/2022 22:44:53	958974.2924	1307851.9214	335.3277	5.1047
UM11	Adjusted	09/03/2022 22:44:53	958886.4540	1307643.3964	337.9675	4.1259
UM12	Adjusted	09/03/2022 22:44:53	958175.6020	1307120.3725	343.4536	11.8581
ZRKD	Control	09/03/2022 22:33:51	352513.3016	1232986.6249	697.2685	13.0606

Figure 4: Adjusted Coordinates (Results) in Eastings and Northings, source Author

The result of the survey was checked and accepted for established the controls. Twelve coordinates are hereby presented in Table 5. The total length between the control points is 7128.43 m.

Table 5 List Third Order Control Station in University of Maiduguri

S/No.	Name	Easting	Northing	Height
1	GMT001	303518.5	1304780	344.090
2	GMT002	303609.6	1305183	340.285
3	GMT003	302810.7	1305618	327.001
4	GMT004	303539.8	1305768	338.509
5	GMT005	303956.2	1306257	320.872
6	GMT006	303970.5	1306858	322.643
7	GMT007	304373.9	1306518	319.073
8	GMT008	304697.7	1306179	334.460
9	GMT009	304815.8	1305881	334.167
10	GMT010	304859.0	1305131	336.956
11	GMT011	304768.1	1304925	338.130
12	GMT012	304047.6	1304416	329.186

CONCLUSION AND RECOMMENDATION.

From the research carried out, the control network was established on the stable ground, twelve set of third order controls were established within the study area (UNIMAID), their positions (coordinates) were determined using Hi-Target V90 differential GPS in real time kinematic method, the time elapse of one hour was used for the establishment of control network and 30 minute was used for the observation on the station. The observed data were observed data were processed using both Hi-Target Business Center (HBC) and LEICA Geo Office 8.4 application software. The resulting data was subjected to statistical test to ascertain its goodness of fit and network connectivity variance of the unit weight/standard error of the unit weight. The test indicates that there are no blunders detected in data. The repeated vector analysis shows that, the data had passed test and quality assurance (QA) test. It is hereby recommended that the results of this study be used for extending such controls to the other parts of the university, particularly on virgin land due to rapid development that is taking place. Also there is also the need to establish second order controls which will be used for geodetic survey especially by postgraduate students from Geomatics Department.

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