Intergrity Check on Ground Control Points Using Nignet's Continuously Operating Reference Stations

Felix IYIOLA, Rasheed OGUNDELE, Caleb OLUWADARE and Olajide KUFONIYI, Nigeria

Key words: GNSS, Mapping, IGS, GCP

SUMMARY

The first requirement for any mapping project is the provision of a network of horizontal and vertical controls. Differential Global Navigation Satellite System (DGNSS), using Continuously Operating Reference System network data is the modern, efficient method for such control establishment as it enables accurate and reliable positioning and navigation. The Office of the Surveyor General of the Federation (OSGOF) of Nigeria initiated a project in 2008 to establish a Nigerian GNSS Reference Network (NIGNET) to serve different applications such as positioning, surveying and mapping, navigation, emergency response, disaster management and location-based services at national and continental levels (Jatau et al, 2010). This project will also contribute to the African Geodetic Reference Frame (AFREF) project. At the time of this report, the country, through OSGOF, has established eleven (11) Continuously Operating Reference Stations (CORS) in different parts of the country while Lagos State has also established one; these stations are permanent and active in nature.

In 2010, Osun State government embarked on the aerial mapping of the entire state at large scale using high resolution aerial photographs (25cm Ground Sampling Distance – GSD) for the development of the state. The aerial photography was preceded by the establishment of one hundred and twenty four signalized (first- and second-order) passive Ground Control Points (GCPs), using Global Navigation Satellite System (GNSS) receivers, for aerial triangulation purpose. The establishment of three (3) COR stations as part of the mapping project was also nearing completion as at the time of this report, with full installation completed, awaiting calibration tests. The focus of this study is to check the integrity of the established passive Ground Control Points using Continuously Operating Reference Stations (CORS) from NIGNET and International GNSS Service (IGS) networks. A sample of the established ground control stations was randomly selected and GNSS receivers were mounted on them to obtain their X, Y and Z coordinates in static mode. The GNSS observations were post-processed with NIGNET and IGS CORS and the results analysed to check the accuracy and reliability of both the ground control points and the NIGNET CORS. It is hoped that the outcome of the study will enhance the confidence of surveyors in the use of the CORS being established by the country and the state for efficient and accurate position determination in the country and Osun State in particular.

1. INTRODUCTION

Global Navigation Satellite System (GNSS) has revolutionized almost all applications that require high-accuracy positioning, navigation and timing. The system has been extensively used for primary geodetic control networks to form the basis for national mapping and to establish the global geodetic networks to define the international reference frame. Technological improvements in GNSS receivers have made GNSS surveying to achieve centimeter-level accuracy positioning in real time without the need for Surveyors to establish their own base stations. Surveyors and other users can now take the advantage of ground infrastructure of permanent Continuously Operating Reference Stations (CORS) to meet the needs of mapping, geodesy, geosciences, navigation, etc. (Scott and Gebre-Egziabher, 2009).

Initially, Global Positioning System (GPS) surveying used static GPS receivers in pairs, post processing observation data using differential techniques. Permanent GPS base stations were later deployed to augment traditional geodetic networks. Individual base stations initially supplied users with data stored on personal computers for post processing via electronic Bulletin Board Service (BBS) technology. Radio transmitters were also located at these base stations for Real Time Kinematic (RTK) positioning (Hale et al, 2006).

As GPS receiver technology began to incorporate the data processing capabilities of base station computers, they became known as Continuously Operating Reference Stations (CORS). The name change was appropriate as operators could confidently rely on continuous receiver and antenna operation for years. BBS technology was replaced by web servers for data distribution. By linking CORS sites using computer networks and the Internet and streaming raw satellite data in near real time to centralised processing facilities, contemporary CORS networks were born. CORS networks also now use the mobile Internet for data distribution to users. A significant advantage of networked CORS corrections, whether real time or post processed, is that position correction can use multiple Reference Stations, effectively eliminating accuracy degradation with increasing range between Reference Stations and rover (Hale et al, 2006).

Mapping is the survey made to determine the locations of natural and cultural features on the earth's surface and to define the configuration (relief) of that surface. The maps produced can be used for many applications such as locations of highways, railroads, pipelines, reservoirs, transmission lines, housing and landscape design; and the maps can also be used extensively in Geographic Information System (GIS) applications.

Osun State government embarked on mapping the entire state at large scale using high resolution aerial photographs for the development of the state. The project was preceded with the establishment of one hundred and twenty four (passive) Ground Control Points (GCP) to cover the state using GNSS receivers. The state also embarked on the establishment of three (3) COR Stations in Osogbo, the state capital, Ikire and Ifetedo. Aerial survey of the state was undertaken to acquire three-dimensional images of ground features from which maps and other numerical information can be produced.

The aim of this study was to ascertain the accuracy and reliability of the Ground Control Points (GCP) established for this mapping exercise. This was achieved by carrying out differential GNSS observations on a sample of the control points, processing the observations using NIGNET CORS data and data from online GPS data processing centre, and analysing the results

Map Source: Google,2012

NIGNET CORS plotted on Google Earth image

Figure 1: NIGNET Continuously Operating Reference Stations (CORS)

The site for the study was chosen such that it covered thirteen of the thirty local governments within the state of Osun, Nigeria. The selected Local Government Areas are Ife South, Ife North, Ife East, Ila, Ayedaade, Ola-Oluwa, Boripe, Boluwaduro, Osogbo, Obokun, Irewole, Ejigbo and Ede North. The sites lie between Latitude 7° 16' 56" N and 7° 58' 06" N and Longitude 4° 09' 01" E and 4° 53' 30" E

Fifteen (15) ground control stations were selected for GPS observation in the selected thirteen (13) local government areas (figure 2), the selected stations and their WGS 84 coordinates are as follows:

Table 1: Existing Ground Control Stations and their coordinates

S/NO	STATION	EASTING (m)	NORTHING (m)	HEIGHT (m)
1	OSC 027P	669938.776	862020.521	338.156
2	OSC 035P	665310.062	817486.793	271.411
3	OSC 036P	676411.600	810546.510	242.044
4	OSC 042P	635637.255	856788.810	330.130
5	OSC 046P	696594.521	874823.375	534.860
6	OSC 047P	662558.867	851109.044	341.622
7	OSC 048P	682046.885	845968.234	343.216
8	OSC 055P	687348.635	877346.665	477.248
9	OSC 057P	699577.347	871544.315	461.243
10	OSC 059P	708511.518	881302.851	513.244
11	OSC 060P	645170.051	861072.090	334.214
12	OSC 061P	646737.114	850837.946	317.987
13	OSC 065P	627056.597	857750.661	288.234
14	OSC 068P	661976.139	805233.682	218.624
15	OSC 022S	670358.209	859325.388	349.036

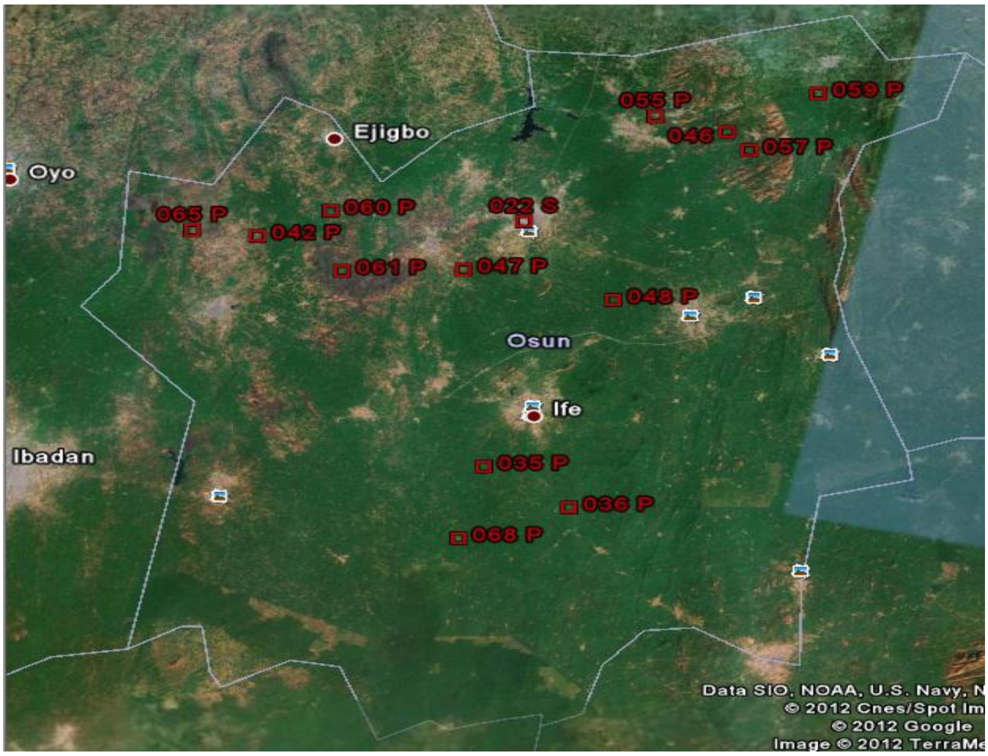

Figure 2: Selected Ground Control Points in the study area (Plotted in Google Earth)

2. HARDWARE/EQUIPMENT USED

The following survey Hardware and equipment were used:

i. Two pairs of Promark 3 GPS receivers
ii. Garmin 72 CSX (Hand-held Receiver)
iii. HP laptop

3. SOFTWARE USED

The following software packages were used:

i. GNSS Solutions (Post processing software for Promark 3 GPS receivers)
ii. Online Processing Software (Canadian Spatial Reference System)
iii. Microsoft Excel 2010

4. FIELD WORK

The coordinates of the selected stations were extracted from the coordinate register and uploaded to hand-held GPS (Garmin 72 CSX) jus to quickly locate their positions on the ground accompanied by the station description sheet.

The GPS receivers for actual observations (Promark 3) were properly configured for field observation using WGS 84 reference ellipsoid. All the selected stations were occupied and differential GPS observation was taken for a period of one (1) hour on each of the observation stations (figure 3).

Figure 3: Field Observation with Promark 3

5. DATA DOWNLOADING AND PROCESSING

Raw GPS data was downloaded from GPS receivers using GNSS Solutions (Promark 3 post-processing software); NIGNET website (www.nignet.net) was visited where CORS Orbit and RINEX data were downloaded using appropriate GPS dates. RINEX data files were unzipped and Hatanaka software was used to obtain full RINEX files for data processing.
Observed raw GPS data was processed using CORS data to obtain latitudes and longitudes of the stations in WGS 84 ellipsoid. The geographical coordinates were later transformed to UTM grid coordinates in WGS 84 reference ellipsoid.

Table 2: NIGNET's COR Stations used and their UTM coordinates in WGS 84

S/N	CORS	Easting (m)	Northing (m)	Height (m)	Location
1	BKFP	633587.955	1378678.224	250.0118	Benin Kebbi
2	OSGF	333621.914	998255.729	532.6447	Abuja
3	RUST	275798.099	531090.780	45.5892	Port Harcourt
4	UNEC	334662.399	710405.317	254.4055	Enugu

Source (OSGoF)

The observation files were converted to RINEX and submitted for online processing using Canadian Spatial Reference System (CSRS) to compare online processing result with the result obtained from NIGNET CORS.

6. ANALYSIS OF RESULT

The coordinates of the selected Ground Control Points (GCP) were obtained from NIGNET CORS and from Canadian Spatial Reference System (CSRS), the online processing centre.
Table 3 shows the existing coordinates of the selected ground stations and the results obtained from the two systems (NIGNET and CSRS), differences in the coordinates between the existing coordinates and the two systems are in column 7, column 8 and column 9 of the table.
Figures 4 and 5 show small differences in easting and northing coordinates between the NIGNET and CSRS when compared with the existing coordinates of the selected ground stations while there is big discrepancy (between 5m and 7m) in heights, figure 9 is an indication that NIGNET and CSRS agreed with each other in heights.
Figure 6 shows small differences in eastings, northings and heights when the results from NIGNET and CSRS were compared.

Big discrepancies in heights when NIGNET and CSRS coordinates are compared with the existing ground station coordinates is an indication that the existing ground station heights should be checked for any source of error.
Figure 6 shows that the coordinates of the Ground Control Points as obtained from NIGNET are consistent and that the NIGNET is a reliable network for geodetic control establishment.
The results obtained also showed that COR Stations in Nigeria are consistent and they can be compared with other COR Stations around the world.

Table 3: Comparison of Results obtained from NIGNET and CSRS with existing coordinates

			A	B	C	Difference in Coordinates		
	STATION		EXISTING	NIGNET	CSRS	A-B	A-C	B-C
1	OSC 027 P	E	669938.776	669939.253	669938.812	-0.477	-0.036	0.441
		N	862020.521	862019.128	862019.725	1.393	0.796	-0.597
		H	338.156	332.194	332.148	5.962	6.008	0.046
2	OSC 035P	E	665310.062	665310.649	665309.740	-0.587	0.322	0.909
		N	817486.793	817485.341	817485.994	1.452	0.799	-0.653
		H	271.411	265.550	265.207	5.861	6.204	0.343
3	OSC 036P	E	676411.600	676412.204	676411.906	-0.604	-0.306	0.298
		N	810546.510	810545.047	810545.629	1.463	0.881	-0.582
		H	242.044	236.217	235.892	5.827	6.152	0.325
4	OSC 042P	E	635637.255	635637.692	635637.764	-0.437	-0.509	-0.072
		N	856788.810	856787.385	856788.241	1.425	0.569	-0.856
		H	330.130	323.796	323.389	6.334	6.741	0.407
5	OSC 046P	E	696683.303	696683.804	696683.676	-0.501	-0.373	0.128
		N	874704.416	874703.010	874703.652	1.406	0.764	-0.642
		H	534.860	528.798	528.816	6.062	6.044	-0.018
6	OSC 047P	E	662558.867	662559.203	662559.534	-0.336	-0.667	-0.331
		N	851109.044	851107.686	851107.706	1.358	1.338	-0.020
		H	341.622	335.665	335.436	5.957	6.186	0.229
7	OSC 048P	E	682046.885	682047.440	682047.039	-0.555	-0.154	0.401
		N	845968.234	845966.825	845967.510	1.409	0.724	-0.685
		H	343.216	337.270	336.866	5.946	6.350	0.404
8	OSC 055P	E	687348.635	687349.116	687349.312	-0.481	-0.677	-0.196
		N	877346.665	877345.526	877346.877	1.139	-0.212	-1.351
		H	477.248	471.315	470.934	5.933	6.314	0.381
9	OSC 057P	E	699577.347	699577.783	699578.631	-0.436	-1.284	-0.848
		N	871544.315	871543.184	871543.661	1.131	0.654	-0.477
		H	461.243	455.301	454.465	5.942	6.778	0.836
10	OSC 059P	E	708511.518	708511.979	708511.757	-0.461	-0.239	0.222
		N	881302.851	881301.735	881301.779	1.116	1.072	-0.044
		H	513.244	507.284	507.599	5.960	5.645	-0.315
11	OSC 060P	E	645170.051	645170.454	645170.977	-0.403	-0.926	-0.523
		N	861072.090	861070.922	861071.875	1.168	0.215	-0.953
		H	334.214	328.097	327.322	6.117	6.892	0.775
12	OSC 061P	E	646737.114	646737.551	646737.610	-0.437	-0.496	-0.059
		N	850837.946	850836.740	850837.373	1.206	0.573	-0.633
		H	317.987	311.838	310.710	6.149	7.277	1.128

13	OSC 065P	E	627056.597	627057.023	627056.708	-0.426	-0.111	0.315
		N	857750.661	857749.444	857750.360	1.217	0.301	-0.916
		H	288.234	281.989	280.756	6.245	7.478	1.233
14	OSC 068P	E	661976.139	661976.756	661976.674	-0.617	-0.535	0.082
		N	805233.682	805232.137	805232.950	1.545	0.732	-0.813
		H	218.624	212.768	213.059	5.856	5.565	-0.291
15	OSC 022S	E	670358.209	670358.704	670357.938	-0.495	0.271	0.766
		N	859325.388	859323.974	859324.298	1.414	1.090	-0.324
		H	349.036	343.051	342.114	5.985	6.922	0.937

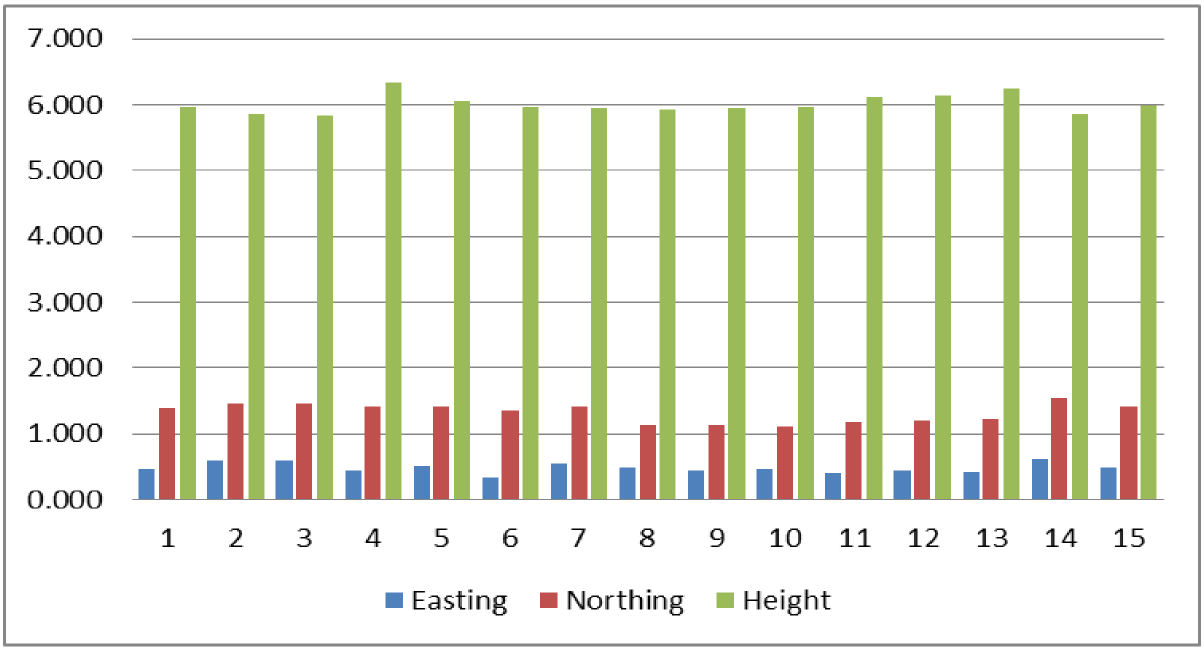

Figure 4: Difference between Existing coordinates and NIGNET

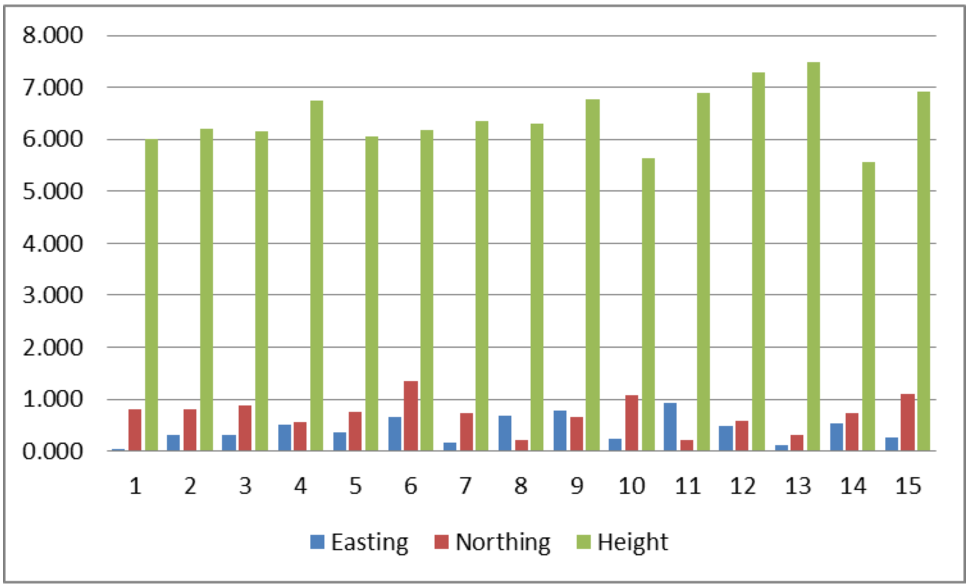

Figure 5: Difference between Existing coordinates and CSRS

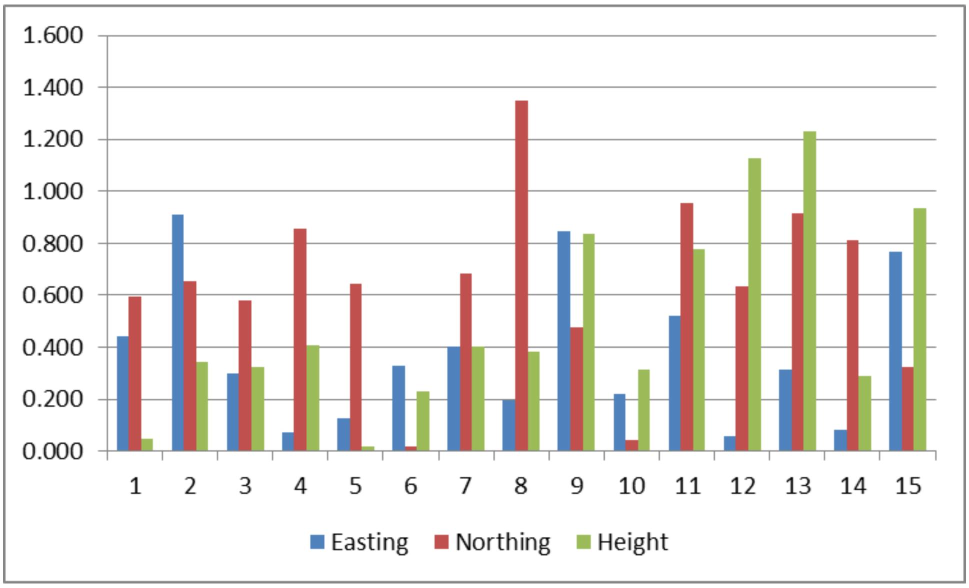

Figure 6: Difference in coordinates between NIGNET and CSRS

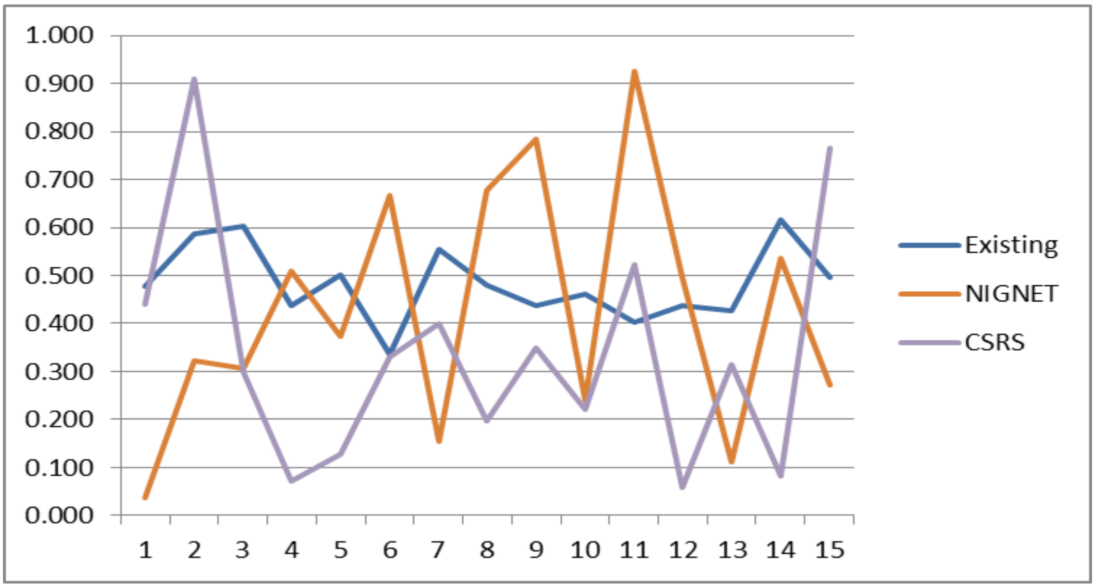

Figure 7: Comparison of Easting coordinates between the three systems

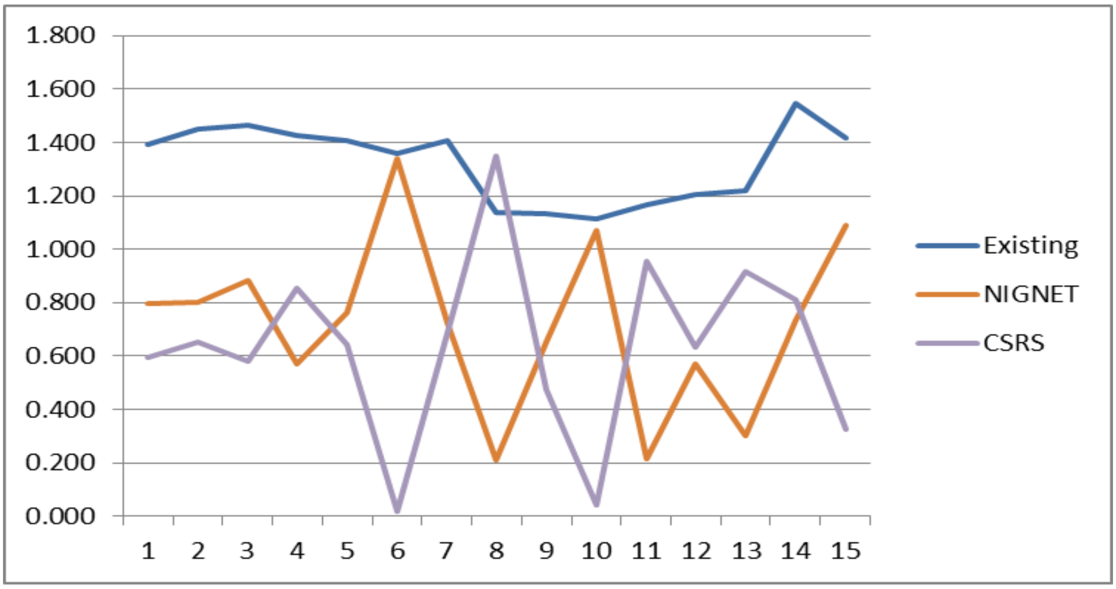

Figure 8: Comparison of Northing coordinates between the three systems

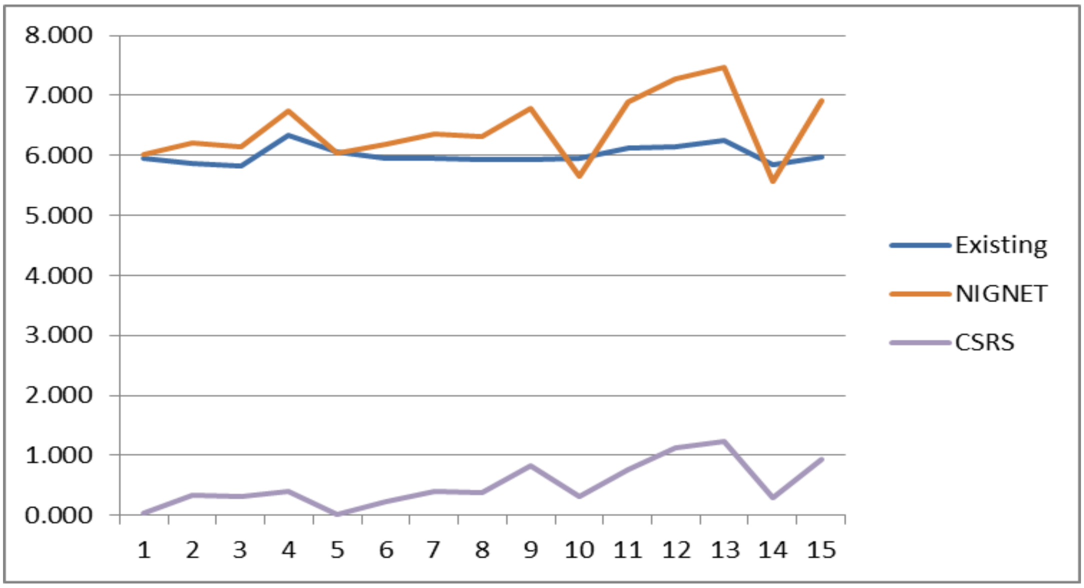

Figure 9: Comparison of Heights between the three systems

7. CONCLUSION

The study has demonstrated the reliability of the nation's CORS network as well as that of the ground control points recently established in the state of Osun. International GNSS Service (IGS) network is a globally distributed Continuously Operating Reference Station (CORS) network and many of these stations are established at national and state levels. NIGNET CORS is similar to IGS stations, the stations have GNSS receivers mounted on them and they operate on a continuous basis. The network downloads data from receivers as RINEX files and they are made available free of charge (in principle) to users for post-processing. Some states like Lagos and Osun have also established one (1) and three (3) COR stations respectively for mapping and other applications in the country.
Effective monitoring and management of natural disasters requires the most recent terrain information, and for this purpose, aerial photographs and satellite imageries when integrated with Geographic Information System (GIS) can yield the best results. For controlling the scale and other errors in the aerial photographs and satellite imageries, ground survey control is absolutely essential. The GNSS surveying technique can be used for this purpose, to yield very accurate results in an efficient and economic way. It is obvious that the Ground Control Points established for the mapping project in Osun State are reliable and will yield accurate results for the project and other applications. The establishment of CORS network in the state will ensure uniform coordinate system and permanently eliminate the use of local origin.

However, to put the CORS network into effective use, it is essential to decide as a matter of national policy and urgency which reference ellipsoid to officially adopt. Is the country going to stick to the use of Clarke 1880 Ellipsoid such that the more accurate measurements obtained from the CORS network but based on WGS 84 as default, will have to be transformed to Clarke 1880 ellipsoid before applications? Or will the country take the bold decision to adopt WGS 84 as the official reference ellipsoid for surveying and mapping? The authors of this paper will like to recommend the latter policy for consideration and adoption.

REFERENCES

Jatau B, Fernandes R. M. S, Adebomehin A. and Goncalves N. (2010): NIGNET-The New Permanent GNSS Network of Nigeria. FIG Congress 2010.

Charles D. G. and Wolf P. R. (2006): Adjustment Computations, Spatial Data Analysis, John Wiley & Sons, Inc Hoboken, New Jersey, 4^{th} Edition

Hale M.J, Collier P.A, Kealy A.M, Ramm P.J and Millner J.C (2006): Validating a Model for CORS Network Management, International Global Navigation Satellite Systems Society Symposium held in Australia, 17-21 July 2006.

Scott G and Gebre-Egziabher D (2009): GNSS Applications and Methods, Artech House 685 Canton Street, Norwood

BIOGRAPHICAL NOTES

Felix Iyiola is a Lecturer at Federal School of Surveying, Oyo, Nigeria. He is the Coordinator of SIWES and Practicals Unit of the school. He holds the following qualifications: PGD (GIS), PGD (Surveying and Geoinformatics) and is currently (at the time of this report) finalizing his M.Sc. studies. He is a registered surveyor and full member of the Nigerian Institution of Surveyors.

Rasheed Ogundele retired voluntarily as Senior Lecturer at Federal School of Surveying, Oyo, Nigeria in 2006. He is the Chief Executive Officer of Arosurge Nigeria Limited with head office in Osogbo, Nigeria. He holds the following qualifications M.Sc. in Environmental Management, PGD (GIS), PGD(Photogrammetry). He is registered to practice surveying in Nigeria and a full member of the Nigerian Institution of Surveyors.

Caleb Oluwadare is an academic staff in the Department of Estate Management, Obafemi Awolowo University, Ile-Ife, Nigeria.
He holds the following qualifications M.Sc. (Remote Sensing and Geographic Information System), B.Sc. (Surveying, Geodesy and Photogrammetry) and is currently on his Ph.D. studies. He is a registered surveyor and a full member of the Nigerian Institution of Surveyors.

Olajide Kufoniyi is a Professor of Geoinformatics at the Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria. He is a former Executive Director of the Regional Centre for Training in Aerospace Surveys (RECTAS) Ile-Ife, Nigeria and former Rector Federal School of Surveying, Oyo, Nigeria. Also, he is registered surveyor and a Fellow of the Nigerian Institution of Surveyors.

CONTACTS

Felix Iyiola
Department of Geoinformatics
Federal School of Surveying, Oyo, Nigeria.
Mobile: +234 803 3955 301
e-mail: felixiyiola@yahoo.com

Rasheed Ogundele
Arosurge Nigeria Limited
Orisunmbare Market, Osogbo, Nigeria.
Mobile: +234 803 3943 589
e-mail: arosurge@yahoo.com

Caleb Oluwadare
Department of Estate Management
Obafemi Awolowo University
Ile-Ife, Nigeria.
Mobile: +234 803 5920 575
e-mail: olucal1@yahoo.com

Prof. Olajide Kufoniyi
Department of Geography
Obafemi Awolowo University
Ile-Ife, Nigeria.
Mobile: +234 803 7251 141
e-mail: jkufoniyi@oauife.edu.ng