ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)
CODEN: GBEEB6

Geological Behavior (GBR)

DOI: http://doi.org/10.26480/gbr.02.2022.101.106

CrossMark

RESEARCH ARTICLE

ASSESSMENT OF 3D POSITIONAL ACCURACY OF GEODETIC OBSERVATIONS FROM SINGLE CORS

Oladosu S. O*., Ehigiator-Irughe R.

Department of Geomatics, Faculty of Environmental Sciences, University of Benin, P.M.B. 1154, Edo State, Nigeria.
****Corresponding author email: olushola.oladosu@uniben.edu***

This is an open access journal distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited

ARTICLE DETAILS

Article History:

Received 20 June 2022
Accepted 04 October 2022
Available online 11 October 2022

ABSTRACT

Geodetic observations for both vertical and horizontal control networks cannot be compromised for any reason in accuracy and precision in the field of geomatics. Due to the error-prone nature of survey measurements, standards are established to allow for comparing the obtained results with a set of guidelines, regulations, or pre-determined specifications. The University of Benin's Ugbowo Campus in Nigeria does not have enough control points, which informs this study. The densification of more reliable control points using the most recent technology is necessary. Before the observations, control network design, excavation, casting, and monumentation of first-order compliance beacons had been completed. Eight GNSS receivers were connected to the CORS_Geosystems multi-link access point and simultaneously deployed for observations. The stages involve the adjustment of observed data, the presentation of adjusted results, and the determination of horizontal and vertical accuracies. The result of horizontal accuracy showed that the RAPH_GNSS_08 station had the highest horizontal accuracy standard ratio of 1:432,193, while the Raph_GNSS_04 station had the lowest, 1:133,271. The highest vertical accuracy standard was 4.0mm, achieved between Cors_Geo and RAPH_GNSS_09, while the lowest, which was 3.1mm, was observed between Cors_Geo and RAPH_GNSS_08. High-precision engineering projects in the research area will benefit from the established first-order controls in terms of execution, monitoring, and maintenance. The Surveyors Council of Nigeria (SURCON) has recommended GNSS as one of the methods for achieving geodetic control densification in Nigeria.

KEYWORDS

Adjustment, CORS, GNSS, Horizontal Accuracy, Vertical Accuracy

1. INTRODUCTION

The accuracy of the final result obtained from control points densification data during post-processing of GNSS observation and data captured through conventional equipment is always compared to some form of predefined specifications, which are the minimum expectation of the control order type in terms of the equipment used, the observation procedures, the methods of checking misclosure, the weather condition and so on, to make the level of accuracy intended attainable (Dimal, 2022). These specifications are provided by the survey agency of a state, or any other national or international surveying regulating body lawfully empowered to do so in a particular country. The Surveyors Council of Nigeria (SURCON), established by CAP 425, Laws of the Federation of Nigeria, 1990, is the body recognised by law to regulate the activities of survey practices in Nigeria. The benefits of the council's specification (s) are that they serve as a guide and minimum benchmark, upon which the limit of allowable error in the control survey must take a premium for classification and order placement. The international regulating bodies include but are not limited to: (i) Intergovernmental Committee on Survey and Mapping (ICSM, 2014), (ii) International GNSS Service (IGS, 2021), (iii) National Oceanic and Atmospheric Administration (NOAA, 2013), and (iv) National Geodetic Survey (NGS, 2021).

The conventional methods of achieving horizontal control establishment as stated by Stibor, (2013) include traversing, triangulation, trilateration, and photogrammetry. GNSS is a modern method with better accuracy. Leveling, gravity measurement, and GNSS techniques are for establishing vertical controls. At best, the GNSS technique only provides an ellipsoidal height, which is unreliable for modeling flow direction and other precision engineering applications. According to Hernández-Andrade et al., (2022), the suitability of the methods of GNSS application will determine the positioning accuracy and signal quality of the obtained GNSS data. The ability to deliver positional accuracy at (cm) or (mm) level depending on the mode of operation, ease of use, and superiority offered over conventional methods have made GNSS equipment and accessories, including the CORS, more appealing to end users (Wu et al., 2015; Singh and Kumar, 2019; Leica Geosystems, 2005).

A single or multiple CORS can accommodate and allow authorised users to connect their single or multiple receivers for static and RTK observations for mapping, stake out, control survey, etc. CORS serves a similar purpose to the previously known DGNSS method by making communication achievable between the "base station" and the "rover receiver." For homogeneous and harmonious positional coordinate solutions, CORS performs better than DGNSS in terms of robustness, refinement, flexibility, accuracy, and the capacity to accommodate multiple receivers concurrently via network communication and data links (Erekosima and Onoriode, 2018; Botsyo et al., 2020). Stone noted that the CORS receiver collects data or information in P-code, C/A-code pseudoranges, L1, and L2 carrier phases (Stone, 1996). With the availability of CORS infrastructure and accessories, recording GNSS data at a known location necessary for relative positioning can be realised (Stone, 1996; Leica Geosystems, 2005).

Quick Response Code	Access this article online	
	Website: www.geologicalbehavior.com	**DOI:** 10.26480/gbr.02.2022.101.106

Cite The Article: Oladosu S. O., Ehigiator-Irughe R. (2022). Assessment of 3d Positional Accuracy of Geodetic Observations from Single Cors. *Geological Behaviour 6(2): 101-106.*

The ICSM, provided the guidelines for CORS installation (ICSM, 2014). While installing CORS_Geosystems in Benin City, Nigeria, these guidelines were carefully followed (Oladosu et al., 2022). The guidelines identified three tiers of CORS categories, but the one used in this research (CORS_Geosystems) is compatible with tier 3, which is suggested for the establishment or extension of first-order ground controls or the densification of the national CORS network. This tier 3 CORS category usually supports real-time positioning applications, operates, and provides access to the datum of reference but does not define it (ICSM, 2014; Öcalan and Tunalıoglu, 2010). The definition of the Nigeria GNSS CORS reference frame has been reported and evaluated by (Jatau et al., 2010; Ayodele et al., 2017; 2020). According to participation of able individuals and institutions of learning in CORS installation will enhance the realisation of the objectives of NIGerian GNSS Reference NETwork (NiGNET) and, by extension, the African Reference Frame (AFREF) core agenda (Oladosu et al., 2022; AFREF, 2016).

Before and after the advent of CORS technology, the method of GNSS survey has existed and remains a vital alternative in developing nations to various degrees due to the cost implication of CORS installation. CORS has been evolving and gradually gaining acceptance in developing nations in the last few years. The advantages of CORS include but are not limited to the following: It enables surveyors to differentially correct static GNSS observations; with it, coordinate accuracy and homogeneity are achievable rover operation errors are well minimized it contributes immensely towards actualising a unified geodetic reference system at local, regional, and global scales such as NIGNET, AFREF, and ITRF cutting of line-of-sight is abolished it saves time and cost hence, more survey grade GNSS receiver users can have access it can aid in the determination of the seasonal variations of the vertical total electron content (VTEC) of the ionosphere over a region it eliminates the compulsory use of a base station for DGNSS observation (Elemo et al., 2018; Moegen et al., 2018; Botsyo et al., 2020; Ali, 2012). A few reviews of some relevant literature on CORS are provided in the following sub-section in terms of implementation, evaluation, assessment, awareness, establishment, and applications.

1.1 Review of Related Literature

A group researchers implemented the establishment of GNSS CORS at Java and Bali regions for Cadastral Survey and Mapping in Indonesia (Abidin et al., 2012). The CORS are needed to speed up the cadastral land registration process since 55% (48 million) of land parcels need certification, and about 90% (83 million ha) of the area is yet to be properly surveyed. A group researcher on the CORS technology advancement in Jeddah showed a departure from the passive geodetic marks to the active control networks (Mousa et al., 2013). The findings showed that the Jeddah CORS/VRS complied adequately with the design specifications and could offer centimeter-level horizontal positioning services to users who could not afford more than a single GNSS receiver. Some researchers investigated and quantified vertical land motion trends in Malaysia using the GNSS technique between 1999 and 2011 (Hassan et al., 2015).

The data used was taken from the Department of Surveying and Mapping Malaysia (DSMM) and comprises (CORS) data over Peninsular Malaysia, Sabah, and Sarawak validated with reference data obtained from the International GNSS Services (IGS) website. The findings demonstrated that the control could predict plate tectonic movements in land uplift and subsidence in the ranges of 0.21 +/- 0.14 mm/yr at MUKH station to 1.44 +/- 0.13 mm/yr at PDIC station and -0.04 +/- 0.04mm/yr at KUAL station to -34.41 +/- 0.16 mm/yr at AMAN station for subsidence rates. Some researchers deployed a CORS-enabled control establishment survey for the rugged terrain synonymous with the Niger Delta region of Nigeria, blessed with oil and gas (Erekosima et al., 2018). The conclusion reveals that the system improves geodetic data integrity, enhances data harmonization, saves time, and ensures quick project delivery. The suggested recommendation is to extend the technology to land information system (LIS) development in Nigeria.

In other study, looked into the seasonal variations of the ionosphere's vertical total electron content (VTEC) at the University of Benin's GNSS CORS and three other CORS spread out across Nigeria (Elemo et al., 2018). The results show that there exists a positive correlation in magnetic longitudes across the ABU, CLBR, and Benin stations, with the Benin station having the least TEC values at all investigated seasons. The Benin station also offers an advantage in terms of positional accuracy. Khai and Long, deployed the CORS-enabled RTK observations technique for large-scale cadastral mapping by testing the accuracy of the positioning solution based on the investigation of selected distances from the CORS base to the rover station (Khai and Long, 2019). The results showed that for the production of cadastral maps at different scales of (1: 200, 1: 500, 1:1000, 1:2000, and 1:5000), the proposed maximum distances from the CORS station to the rover station are 2.2 km, 5.3 km, 10.5 km, 20.8 km, and 51.7 km, respectively.

Mlambo and Ali conducted research in Zimbabwe using questionnaires and focus group discussion techniques to assess the level of awareness of the relevant stakeholders and GNSS users about (i) knowledge of CORS technology, (ii) access to GNSS equipment compatible with CORS, (iii) prior experience with CORS, (iv) skills in the manipulation of CORS (Mlambo and Ali, 2020). The result showed that more than 50% of the respondents have access to GNSS equipment, but the result was discouraging in the aspects of the frequency of use and preparedness of stakeholders to upgrade to GNSS CORS equipment, applied a CORS GNSS survey at different ranges in Accra, Ghana (Botsyo et al., 2020). The test results showed that for both single and dual frequency modes, observations made within a range of 23 km from the CORS produced an average positional variation in northings and eastings of 0.790 m, 0.176 m, and 0.681 m, 0.098 m.

In contrast, at other stations where the range is greater than 25 km from the CORS, the change in northings and eastings is 0.536 m, 0.007 m, and 1.370 m, respectively. A group researchers observed fifteen existing ground control points located within Benin City using Tersus GNSS receivers (A&B) concurrently (Oladosu et al., 2022). Statistical analysis of observations and the Chi-square test at (a 95%) confidence level was reliable. The means of Eastings and Northings rarely exceed 0.007m, and 0.003m, and the standard errors (σ) in E and N are 0.003m, and 0.007m, respectively. This work aims to test the effectiveness of the positioning solutions provided by CORS_Geosystems for the newly established first-order control within the University of Benin, Ugbowo campus and further cross-check the results obtained with the standards specified by SURCON, the surveying, and mapping regulating body in Nigeria. The conclusion is therefore drawn based on the results obtained.

2. MATERIALS AND METHODS

2.1 Study Area

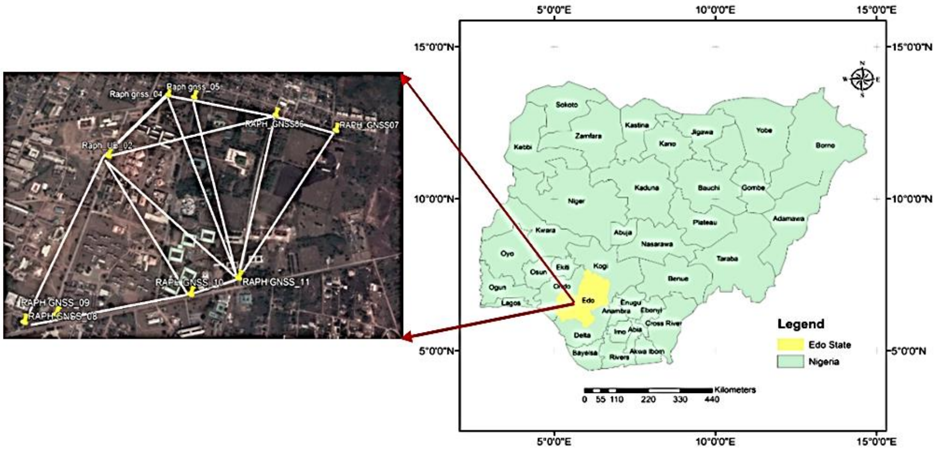

Figure 1: Map of Nigeria showing Edo State and the study area

The study area falls within zone 31N of the Universal Transverse Mercator (UTM) with the following coordinates: (791979.716E, 700426.07N; 789884.712E, 708294.453N). It comprises the CORS_Geosystems location relative to the respective control stations on campus whose coordinates are to be determined. Details on the installation and validation of the CORS_Geosystems can be found in (Oladosu et al., 2022). Excavation, casting, and monumentation of eight controls were completed in accordance with the specification for the first order by the SURCON. The control network designed could accommodate eight receivers at the same time. Independent check was conducted on one of the existing control points with known coordinates to ascertain the performance of the CORS before proceeding with proper surveying. Figure 1 shows the control network configuration and the map of Nigeria showing Edo State and the study location while Figure 2 shows the conceptual framework.

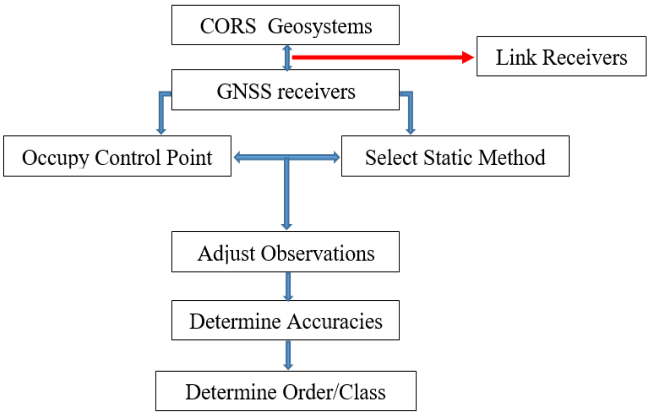

Figure 2: Conceptualization of The Workflow

2.2 GNSS CORS Observations

The validation of the functionality of the CORS_Geosystems has been verified to be adequate (Oladosu et al., 2022). CORS_Geosystems acts as a reference station, broadcasting all corrections to the appropriate GNSS receivers to ensure proper positioning. Satellite trilateration basically adopts a pseudo-range measurement between space satellites and the points whose locations are required to determine their respective positions on the earth's surface. To accomplish this, various methods such as single, double, and triple difference can be used, with each method helping to improve positioning by eliminating some known GNSS observation errors. At least four satellites are required to fix position but having as many satellites as possible increases the accuracy of positioning. CORS is a distance-dependent error reduction technique that can also perform as a DGNSS system to reduce biases (European Space Agency, 2018). The basic algorithm procedures are described in equations 1, 2, and 3. At a given epoch for a specific satellite, the simplified carrier phase observation equation is given by equation (1) (ESA, 2018).

$$\varphi = \rho - I + Tr + C(b_{Rx} - b_{Sat}) + N\lambda + \varepsilon_{\varphi} \tag{1}$$

Where: I, is the signal path delay resulting from ionosphere effect; Tr, is the signal path delay caused by troposphere influence; b_{Rx}, is the receiver clock offset from the reference (GNSS) time; b_{Sat}, is the satellite clock offset from the reference (GNSS) time; C, is the speed of light in vacuum; λ, is the carrier nominal wavelength; N, is the ambiguity of the carrier-phase (integer number); ε_{φ}, are the measurement noise components, including multipath and other effects; ρ, is the geometrical range between the satellite and the receiver. The pseudo-range measurement can be computed in 3D for the satellites $(x_{Sat}, y_{Sat}, z_{Sat})$ and the receivers (x_{Rx}, y_{Rx}, z_{Rx}) using equation (2).

$$\rho = \sqrt{(x_{Sat} - x_{Rx})^2 + (y_{Sat} - y_{Rx})^2 + (z_{Sat} - z_{Rx})^2} \tag{2}$$

For two receivers a and b making simultaneous measurements at the same nominal time to satellites *1* and *2*, the double difference observable takes the form of equation (3):

$$\varphi_a^{12} - \varphi_b^{12} = \rho_a^{12} - \rho_b^{12} - I_a^{12} + I_b^{12} + Tr_a^{12} - Tr_b^{12} + \lambda(N_a^{12} - N_b^{12}) + \varepsilon_a^{12} - \varepsilon_b^{12} \tag{3}$$

In equation (3), the receiver and the satellite clock offsets and the hardware biases are removed. The single difference ambiguities $N_a^{12} - N_b^{12}$ is commonly parameterized as a combined to form a new ambiguity parameterN_{ab}^{12}. The advantage of double differencing is that the new ambiguity parameter N_{ab}^{12} is an integer because the non-integer terms in the GNSS carrier phase observation, due to clock and hardware delays in the transmitter and receiver, are eliminated.

3. DATA PROCESSING AND NETWORK ADJUSTMENT BACKGROUND

Processing GNSS acquired data relies mainly on the principle of least squares adjustment, in which the sum of squares of the residuals must be the minimum. We were able to process the data quickly by using the least squares observation equation model solution for the parametric method, which has already been programmed into the Trimble business center software. The networks and baselines were adjusted to derive the final coordinates of the established controls. The least square procedures can be accomplished using equations 4 to 12:

$$\phi = \sum v^2 = min \quad or \ \sum pv^2 = \ min \tag{4}$$

$$AX = L + V \tag{5}$$

The Least square solution of the unknown parameters is given as:

$$X = (A^T PA)^{-1}(A^T PL) \tag{6}$$

Where X = vector of unknowns, A = the designed matrices, L = the observed parameters, V = the residuals, and P = weighted parameters:

$$A = \begin{Bmatrix} \frac{x_0-x^1}{\rho} & \frac{y_0-y^1}{\rho} & \frac{z_0-z^1}{\rho} & c \\ \frac{x_0-x^2}{\rho} & \frac{y_0-y^2}{\rho} & \frac{z_0-z^2}{\rho} & c \\ \frac{x_0-x^m}{\rho} & \frac{y_0-y^m}{\rho} & \frac{z_0-z^m}{\rho} & c \end{Bmatrix} \tag{7}$$

$$V = AX - L \tag{8}$$

The estimated variance factor is:

$$\sigma_0^2 = \frac{V^T.W.V}{r} \tag{9}$$

The estimated variance covariance matrix of parameters is contained in equation (10)

$$C_X = \sigma_0^2.N^{-1} \tag{10}$$

$$N^{-1} = (A^T PA) \tag{11}$$

Where N, is the solution to the normal equation

Conclusively, the variance covariance matrix of the adjusted observations can be computed as:

$$C_L = A \ .C_X .A^T \tag{12}$$

Figure 3 shows the network adjustment post-processing stage with the CORS_Geosystems. The CORS is fixed because its coordinates are known, whereas the unknown coordinates of other stations were determined. The adjustments' results are later presented in the results section.

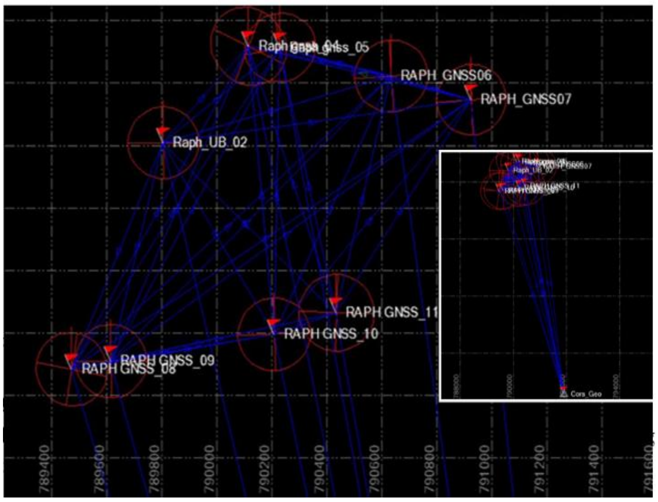

Figure 3: Post-processing of acquired data

3.1 Determination Of Horizontal Accuracy

The determination of horizontal accuracy standard for each baseline was achieved using the linear accuracy formula presented in equation 13 (Ehigiator and Oladosu, 2018).

$$1{:}\left\{{[Vx^2+Vy^2]^{1/2}}\Big/{l_{ac}}\right\} \tag{13}$$

Where: Vx, Vy are the baseline residuals of the 2D coordinates, l_{ac} is the respective baseline lengths. Accuracy in part per million (ppm) can be obtained by multiplying equation (13) by 1,000,000 (Ehigiator and Oladosu, 2018; Ehigiator-Irughe and Audu, 2016).

3.2 Determination of Vertical Accuracy

The determination of vertical accuracy is done in a similar way except that it only utilized the z-coordinate component and the baseline lengths. Equation (14) shows the formula used for vertical accuracy computation (Ehigiator and Oladosu, 2018; Ehigiator et al., 2017; Ehigiator-Irughe and Audu, 2016).

$$1{:}\left\{{[Vz^2]^{1/2}}\Big/{l_{ac}}\right\} \tag{14}$$

Where: Vz, is the baseline residuals in the 1D coordinate, l_{ac} is the respective baseline lengths. Similarly, accuracy in part per million (ppm) can be determined by multiplying equation (14) by 1,000,000.

4. RESULTS AND DISCUSSION

The results of the accuracy obtained for the horizontal and vertical coordinates of the newly established eight control stations are presented in this section. In terms of lengths (distances), Table 1 shows the relationship between each control point and the CORS_Geosystems. The 3D coordinates, residual errors, horizontal accuracy ratio, and horizontal accuracy to the nearest part per million (ppm) are all included. Between the Cors_Geo and Raph_gnss_04, the highest accuracy (ppm) was achieved. The Cors_Geo and Raph_GNSS_05, RAPH_GNSS07, and Raph_UB_02 achieved 4ppm accuracy, while the others achieved 3ppm. The longest distance was 8.3 kilometers between Cors_Geo and Raph_gnss_04, and the shortest distance was 7.4 kilometers between Cors_Geo and RAPH_GNSS_10. Check Table 1 for a summary of the computations and the presentation of other horizontal accuracy data.

Table 1: Horizontal Accuracy

From STN	To STN	Northing (m)	Easting (m)	Elevation (m)	Vx	Vy	Length (m)	Horiz. Accuracy Ratio	Horiz Accuracy (ppm)
Cors_Geo	Raph gnss_04	708605.325	790196.019	114.733	0.010	0.002	8366.055	1:133271	8
Cors_Geo	Raph gnss_05	708599.165	790309.969	112.990	0.002	0.001	8336.499	1:244902	4
Cors_Geo	RAPH GNSS_08	707567.514	789552.402	124.409	0.002	0.002	7537.808	1:432193	3
Cors_Geo	RAPH GNSS_09	707593.159	789693.985	122.840	0.002	0.002	7517.880	1:326210	3
Cors_Geo	RAPH GNSS_10	707681.041	790289.661	114.500	0.002	0.002	7444.385	1:327816	3
Cors_Geo	RAPH GNSS_11	707749.147	790514.686	111.709	0.002	0.002	7463.330	1:327399	3
Cors_Geo	RAPH_GNSS06	708509.201	790714.857	110.820	0.002	0.002	8176.172	1:312802	3
Cors_Geo	RAPH_GNSS07	708433.175	791005.079	110.654	0.002	0.001	8060.947	1:249053	4
Cors_Geo	Raph_UB_02	708294.453	789884.712	121.023	0.002	0.001	8137.237	1:247883	4

The vertical accuracy result is presented in Table 2. The following can be deduced from it: Cors_Geo and RAPH_GNSS_07, RAPH_GNSS_09, and RAPH_GNSS_10, respectively, achieved the highest vertical accuracy of (10ppm) rounded up to the nearest whole number. Raph_gnss_05 and Raph_UB_02 each had the lowest accuracy of 1ppm. The rest of the stations have accuracies of 8ppm and 9ppm. The respective distances of stations from the CORS_Geosystems, the residuals, and the 3D coordinates after the adjustment are among the other details.

Table 2: Vertical Accuracy

From STN	To STN	Northing (m)	Easting (m)	Elevation (m)	Vz	Length (m)	Vert. Accuracy Ratio	Vert. Accuracy (ppm)
Cors_Geo	Raph gnss_04	708605.325	790196.019	114.733	0.010	8366.055	1:109330	9
Cors_Geo	Raph gnss_05	708599.165	790309.969	112.990	0.009	8336.499	1:985713	1
Cors_Geo	RAPH GNSS_08	707567.514	789552.402	124.409	0.011	7537.808	1:126698	8
Cors_Geo	RAPH GNSS_09	707593.159	789693.985	122.840	0.010	7517.880	1:115333	10
Cors_Geo	RAPH GNSS_10	707681.041	790289.661	114.500	0.009	7444.385	1:104311	10
Cors_Geo	RAPH GNSS_11	707749.147	790514.686	111.709	0.010	7463.330	1:115753	9
Cors_Geo	RAPH_GNSS06	708509.201	790714.857	110.820	0.010	8176.172	1:110592	9
Cors_Geo	RAPH_GNSS07	708433.175	791005.079	110.654	0.009	8060.947	1:100242	10
Cors_Geo	Raph_UB_02	708294.453	789884.712	121.023	0.009	8137.237	1:997709	1

The standard for comparison of the obtained results for horizontal accuracy is presented in Table 3. The ratio of the minimum allowable linear misclosure provided by SURCON is 1:100,000. To determine whether our results complied with the given standard, we used the linear misclosure equation in Table 3 to determine the class/order of the newly established controls. Inspection revealed that all stations met the condition's requirements and even outperformed them. RAPH_GNSS_08 had the most accurate control with a misclosure ratio of 1:432,193, while Raph_gnss_04 had the least accurate control with a misclosure ratio of 1:133,271. We deduced from these misclosure ratios that all of the controls are first order, as required.

The Federal Geodetic Control Committee and SURCON, provided a means of computing the vertical accuracy of geodetic vertical control (FGCC, 1984; SURCON, 2007). The difference in elevation accuracy between baselines denoted with "b" expresses this relationship. The accuracy is computed from a minimally constrained and correctly weighted least squares adjustment using the relation in equation (15) (FGCC, 1984).

$$b = S/\sqrt{d} \tag{15}$$

Where: d, is the approximate horizontal distance in (km) between control point positions, S, is the propagated standard deviation of elevation difference in (mm) between survey control points obtained from the least squares adjustment. The units of measurement of “b” are$(mm)/\sqrt{(km)}$.

For the first order, class II vertical control, the allowable misclosure in elevation provided by SURCON is$0.6mm/\sqrt{km}$. The class was determined directly using the known parameter, whereas the class obtained was determined using the misclosure values recorded. As a result, the accuracy of the vertical relationship between the CORS_Geosystems and the height of the respective stations is calculated in terms of difference. Cors_Geo and RAPH_GNSS_09 had the highest class of 4.0mm, while Cors_Geo and the RAPH_GNSS_08 baseline had the smallest class of 3.1mm. Hence, the standard for comparison of the standard results versus results obtained for vertical accuracy is presented in Table 4.

Table 3: Horizontal Accuracy Standard

Baseline		**Class Description**	**Allowable Linear Misclosure** $\frac{\sqrt{\Delta x^2+\Delta y^2}}{\sum L}$	**Total Dist.(M)**	Δx	Δy	**Obtained Linear Misclosure** $\frac{\sqrt{\Delta x^2+\Delta y^2}}{\sum L}$
Cors Geo	Raph gnss_04	First Order	1:100,000	8366.055	0.010	0.002	1:133,271
Cors Geo	RAPH GNSS_08	First Order	1:100,000	8336.499	0.002	0.001	1:244,902
Cors Geo	RAPH GNSS_09	"	"	7537.808	0.002	0.002	1:432,193
Cors Geo	RAPH GNSS_10	"	"	7517.880	0.002	0.002	1:326,210
Cors Geo	RAPH GNSS_11	"	"	7444.385	0.002	0.002	1:327,816
Cors Geo	RAPH_GNSS06	"	"	7463.330	0.002	0.002	1:327,399
Cors Geo	RAPH_GNSS07	"	"	8176.172	0.002	0.002	1:312,802
Cors Geo	Raph_UB_02	"	"	8060.947	0.002	0.001	1:249,053
Cors Geo	Raph gnss_05	"	"	8137.237	0.002	0.001	1:247,883

Table 4: Vertical Accuracy Standard

Baseline		**Distance (km)**	**Obtained Misclosure (mm)**	**Class Determination** $0.6mm/\sqrt{km}$	**Class Obtained** $mm/\sqrt{km}$	**Class**
Cors_Geo	Raph gnss_04	8.4	10	0.21	3.4	II
Cors_Geo	RAPH GNSS_08	8.3	9	0.21	3.1	II
Cors_Geo	RAPH GNSS_09	7.5	11	0.22	4.0	"
Cors_Geo	RAPH GNSS_10	7.5	10	0.22	3.6	"
Cors_Geo	RAPH GNSS_11	7.4	9	0.22	3.3	"
Cors_Geo	RAPH_GNSS06	7.5	10	0.22	3.6	"
Cors_Geo	RAPH_GNSS07	8.2	10	0.21	3.5	"
Cors_Geo	Raph_UB_02	8.1	9	0.21	3.2	"
Cors_Geo	Raph gnss_05	8.1	9	0.21	3.2	"

5. CONCLUSION

The horizontal and vertical accuracies were calculated using data collected during the densification of control stations at a Nigerian university. Application of CORS_Geosystems is a pioneering frontier in the establishment of control points in Edo State. Following the determination of horizontal and vertical accuracies, the obtained results were compared to the survey regulating body's standard and specification guide. As a result, we conclude that the horizontal accuracy standard results were better than the specified 1:100,000. The obtained vertical control of first-order class II with values in millimeters again shows a good height relationship with respect to the reference station. The horizontal and vertical accuracy standards obtained were better, implying that the GNSS equipment used in this study is accurate enough to provide the required standard. It is recommended that this new area of research, particularly in developing countries, be fully embraced. In Nigeria, little has been done to promote the use of CORS GNSS in the establishment of control densification.

ACKNOWLEDGEMENT

The authors are grateful to Geosystems & Environmental Engineering Company LTD. 140, 2nd East Circular Road, Benin City for making the CORS_Geosystems and the GNSS receivers available.

REFERENCES

Abidin, H.Z., Haroen, T.S., Mudita, I., Adiyanto, F.H., 2012. Implementation of GPS CORS for Cadastral Survey and Mapping in Indonesia: Status, Constraints and Opportunities FIG Working Week 2012 TS06E - GNSS CORS Infrastructure and Applications II, Pp. 5900. Rome, Italy.

AFREF, 2016. African Geodetic Reference Frame (AFREF)-Newsletter No. 18. Retrieved August 20, 2021, from: https://www.rcmrd.org ›

Ali, T., 2012. Positioning with Wide-Area GNSS Networks: Concept and Application. Positioning, 3 (1), Pp. 1-6. doi: 10.4236/pos. 2012.31001.

Ayodele, E.G., Okolie, C.J., Ezeigbo, C.U., Fajemirokun, F.A., 2017. Evaluation of Continuously Operating Stations (CORS) Data for the Definition of Nigerian Geodetic Reference Frame. Nigerian Association of Geodesy General Assembly/Conference. Port-Harcourt, Pp. 1-21.

Ayodele, E.G., Okolie, C.J., Ezeigbo, C.U., Fajemirokun, F.A., 2020. Evaluating the Stability and Adequacy of NIGNET for the Definition of Nigerian Geodetic Reference Frame. Nigerian J. of technol developt, 17 (1).

Botsyo, S., Bortei, B.B., Ayer, J., 2020. CORS Usage for GPS Survey in the Greater Accra Region: Advantages, Limitation, and Suggested Remedies. J geovis spat anal, 4, 20. https://doi.org/10.1007/s41651-020-00061-8

Dimal, M.O.L., 2022. Introduction to Control Surveying. Retrieved September 28, 2022 from: https://www.academia.edu/10750910/Introduction_to_Control_Surveying

Ehigiator, M.O., Oladosu, S.O., 2018. Determination of Conversion Constant between Lagos Datum and Niger Delta Mean Lower Low Water Datum and their Horizontal and Vertical Accuracy Standards using GNSS Observations. Nigerian Journal of Environmental Sciences and Technology (NIJEST), 2 (1), Pp. 56 – 68.

Ehigiator, M.O., Oladosu, S.O., Ehigiator-Irughe, R., 2017. Densification of (GNSS) Control points for Cadastral and Mapping Purposes. Nigerian Journal of Environmental Sciences and Technology (NIJEST), 1 (2), Pp. 287-298.

Ehigiator-Irughe, R., Audu, A.P., 2016. Determination of Horizontal and vertical Positional Accuracy from GNSS Geodetic observation. Tropical Environment., 13 (1), Pp. 34-45.

Elemo, E.O., Ehigiator, M.O., Ehigiator-Irughe, R., 2018. Seasonal variations of the vertical total electron content (VTEC) of the ionosphere at the GNSS COR Station (SEERL) Uniben and three other CORS stations in Nigeria. Nigerian Journal of Technology (NIJOTECH), 37 (2), Pp. 286–293.

Erekosima, M., Onoriode, B., 2018. GPS CORS Technology Implementation in the Oil Industry- Benefits and Challenges. Embracing our smart world where the continents connect: enhancing the geospatial maturity of societies (9459) FIG Congress. Istanbul, Turkey.

European Space Agency, 2018. RTK Fundamentals navipedia. Retrieved May 31, 2022 from http://www.navipedia.net/index.php/RTK_Fundamentals.

Federal Geodetic Control Committee FGCC, 1984. Standards and Specifications for Geodetic Control Networks. Rockville, Maryland 20852. Pp 1-34. Retrieved May 31, 2022, from https://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.pdf.

Hernández-Andrade, D., Romero-Andrade, R., Sharma, G., Trejo-Soto, M.E., Cabanillas-Zavala, J.L., 2022. Quality assessment of Continuous Operating Reference Stations (CORS) - GPS stations in Mexico. Geodesy and Geodynamics, 13 (3), Pp. 275-287.

Intergovernmental Committee on Survey and Mapping ICSM, 2014. Permanent Committee on Geodesy (PCG), Guideline for Continuously Operating Reference Stations Special Publication 1, Version 2.1

International GNSS Service IGS, 2021. IGS station Map and Lists. Retrieved 28th July, 2021 from https://www.igs.org/network

Iyiola, F., Ogundele, R., Oluwadare, C., Kufoniyi, O., 2013. Integrity Check on Ground Control Points Using NIGNET's Continuously Operating Reference Stations. FIG Working Week, Abuja, Nigeria, Pp. 1-13.

Jatau, B., Fernandes, R.M.S., Adebomehin, A., Gonçalves, N., 2010. NIGNET-The New Permanent GNSS Network of Nigeria (4549) GNSS CORS Networks - Infrastructure, Analysis and Applications II. Facing the Challenges. Building the Capacity Sydney, Australia, FIG Congress.

Khai, P.C., Long, N.Q., 2019. Accuracy assessment of the single CORS technology for establishing the large-scale cadastral map. International Journal of Scientific & Engineering Research, 10 (5).

Leica Geosystems, 2005. GPS Reference Stations and Networks: An introductory guide. Copyright Leica Geosystems AG, Heerbrugg, Switzerland, 2005. 747352en-IV.05-RVA

Mlambo, R., and Ali, F., 2020. Establishment of Continuously Operating Reference Stations (CORS) in Zimbabwe an exploration of stakeholders' readiness in adopting the CORS technology. African Journal on Land Policy and Geospatial Sciences, 3 (3), Pp. 2657-2664.

Moegen, N.D., Hill, C., Cairns, S., 2018. The Benefits and Challenges of Implementing a Continuously Operating Reference Stations (CORS) GNSS Network in Emerging Countries Leica Geosystems (France, Switzerland, United Kingdom)

Mousa, A.E., Elhattab, A.I., and Suhail, A., Elmadani, S.A., 2013. Jeddah CORS/ VRS: Design, Establishment, and Testing. Port Said Engineering Research Journal Faculty of Engineering - Port Said University, 17 (2), Pp. 96 – 104.

National Geodetic Survey NGS, 2021. NOAA CORS Network (NCN) CORS FAQs. Retrieved March 8, 2021 from https://geodesy.noaa.gov/CORS/cors_faqs.shtml

National Oceanic and Atmospheric Administration NOAA, 2013. Guidelines for New and Existing Continuously Operating Reference Stations (CORS). National Geodetic Survey - National Ocean Survey, NOAA, 1-21

Öcalan, T., Tunalıoglu, N., 2010. Data communication for real-time positioning and navigation in global navigation satellite systems (GNSS)/continuously operating reference stations (CORS) networks. Scientific Research and Essays, 5 (18), Pp. 2630-2639.

Oladosu, S.O., Ehigiator-Irughe, R., Muhammad, M.B.M.E., 2022b. Establishment and Validation of Continuously Operating Reference Stations Geosystems Network on Static and Real-Time Kinematic in Benin City, Nigeria J. Appl. Sci. Environ. Manage., 26 (5), Pp. 801-808.

Singh, S.K., Kumar, D., 2019. Continuously Operating Reference Stations (CORS) GNSS Network Challenges and Benefits in the Indian Context (9921). FIG Working Week 2019 Geospatial information for a smarter life and environmental resilience Hanoi, Vietnam, April 22–26.

Stibor, M., 2013. Horizontal control surveys. Retrieved September 28, 2022, from: https://structural-analyser.com/domains/Surveying/chapter07/

Stone, W.A., 1996. An Overview of Global Positioning System Continuously Operating Reference Stations. Retrieved May 10, 2022, from https://www.ngs.noaa.gov/PUBS_LIB/GPS_CORS.html

Surveyors Council of Nigeria SURCON, 2007. Specifications for Geodetic Surveys in Nigeria. GPS Surveys Specifications, Pp. 44-46. Lagos-Nigeria.

Wu, Q., Kang, J., Li, S., Zhen, J., Li, H., 2015. GNSS Positioning by CORS and EGM2008 in Jilin Province, China. Sensors (Basel, Switzerland), 15 (12), Pp. 30419–30428. https://doi.org/10.3390/s151229806

Cite The Article: Oladosu S. O., Ehigiator-Irughe R. (2022). Assessment of 3d Positional Accuracy of Geodetic Observations from Single Cors. *Geological Behaviour 6(2): 101-106.*