

Validation of Control Points along Auchi – Afuze Road, Edo State, Nigeria

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| ARTICLE INFORMATION | ABSTRACT |
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| <p>Article history: Published on 23rd Jan 2026</p> <p>Keywords: Control points Geodetic survey Surveying reliability Re-observe Validation</p> | <p>This study presents the results of a survey aimed at re-observing and confirming the control points along the Auchi–Afuze Road in Edo State, Nigeria. The control points, which serve as reference points for various engineering and geospatial applications were re-observed using modern surveying techniques to ensure their accuracy and reliability. The study highlights the importance of maintaining accurate control points for infrastructure development, mapping, and other applications. By combining fixed control stations, CORS data, and post-processing with Hi-Target Geomatics Office, it confirmed the positional stability of the network and updated disturbed or missing stations. Comparison between 2022 and 2025 data showed most control points remained stable, except AME036A, which required re-establishment due to noticeable shifts. The transformation from WGS 84 to Minna datum was successfully applied, matching expected parameters. The study followed a rigorous methodology beginning with office and field reconnaissance, followed by data acquisition using dual-frequency GNSS receivers. Post-processing was conducted using Hi-Target Geomatics Office (HGO), involving baseline processing, data cleaning, and network adjustment under both WGS 84 and Minna datum (based on Clarke 1880 RGS ellipsoid). The processed coordinates were exported and compared with those observed in 2022 to assess positional changes. The comparison revealed that most control points experienced minimal shifts, typically within ± 0.02 m in horizontal components and ± 0.4 m in elevation, confirming the stability and reliability of the control network. Spatial visualization of the updated coordinates was carried out using AutoCAD Map 2024, while second-order accuracy specifications were maintained throughout the work. Challenges like poor satellite signals and inaccessible points were managed through careful planning and software adjustments. The project underlined the importance of preserving control points, consistent documentation, and building technical capacity. It confirmed GNSS surveying's reliability and provided recommendations to improve Nigeria's geospatial infrastructure.</p> |

1. Introduction

Surveying is defined as the art, science and technology of measurement of the relative position on natural and man-made features on or beneath the earth surface and the presentation of the processed data (information) graphically or numerically. It is the technique and science of accurately determining the terrestrial or three-dimensional position of points and distances and angles between them. These points are usually on the earth surface, and they often used to establish land maps and boundaries of individual, corporate body and government purpose. The history of surveying dates back to ancient civilizations, where it played a fundamental role in land division, construction, and resource management. (Genovese, 2005).

The earliest evidence of surveying practices can be traced to ancient Egypt, where surveyors, known as “rope stretcher” used primitive tools such as ropes and plumb bobs to measure land for taxation and construction of monumental structure like the pyramids. Similarly, in Mesopotamia, rudimentary surveying techniques were used to establish land boundaries for agriculture. The Greeks made significant advancements in the field, with scholars like Eratosthenes and Hipparchus developing early geodetic concepts, including the measurement of the Earth's circumference. The 18th and 19th centuries witnessed significant advancements with the advent of triangulation methods and precise leveling techniques, which were instrumental in large-scale mapping and national boundary surveys. The invention of the electronic distance measurements over long distances. *Brinker, et al.*; (1995). The introduction of satellite-based positioning systems, such GPS, in the late 20th century further transformed surveying, enabling real-time, high-precision geospatial data collection on a global scale.

Survey control point is a fundamental process in geodetic and topographic surveying that ensures accuracy and consistency in mapping and measurement tasks. Control points serve as fixed reference positions on the earth's surface and are used as benchmarks for locating and orienting subsequent surveys. The process of establishing control points typically involves reconnaissance, selection of stable locations, monumentation, precise measurement, and network adjustment. El-Rabbary, (2006) technique such as triangulation, trilateration, GNSS (Global Navigation Satellite Systems), total stations, or precise leveling are often used to ensure high accuracy. Global Navigation Satellite System (GNSS), including GPS, have revolutionized the establishment of survey control points. These systems provide real-time positioning data and are integral for establishing points over large areas, especially where traditional line-of-sight methods like triangulation are impractical (El-Rabbary, 2006). Continuously Operating Reference Stations (CORS) play a crucial role in the establishment of control networks, providing a foundation for high-precision geodetic and surveying applications. A CORS network consists of permanently installed GNSS receivers that continuously collect satellite data, offering precise positional information in real-time or for post-processed solutions. These stations eliminate the need for temporary base stations by broadcasting corrections to GNSS users within their coverage area, significantly enhancing efficiency and accuracy in field operation. Re-observation or re-confirmation of control points is a critical process to ensure the continued accuracy and reliability of a control network. This involves periodically re-surveying established control points using the same or enhanced methods as were initially applied. Re-observation helps identify any shifts or deformations caused by environmental factors, construction activities, or natural disasters. By detecting and correcting discrepancies, this process maintains the integrity of the geodetic framework. (El-Rabbary, 2006). Re-observation also enhances the robustness of control networks in areas prone to dynamic environmental conditions, such as seismic zones or regions undergoing significant urbanization. Periodic verification strengthens the confidence of engineers, surveyors, and planners in the reliability of control points. This process is often mandated by regulatory frameworks or industry standards to ensure safety and accuracy in critical applications. Moreover, re-observation supports the identification of obsolete or damaged markers enabling their timely replacement or re-establishment. Effective documentation and analysis of re-observation results are essential to update control point databases and maintain their utility for future surveying and mapping projects. This iterative process ensures that control networks remain relevant and operational over time, adapting to both technological advancements and changing environmental conditions.

Various researchers have carried out related studies in different areas. Ogunsanya and Adebayo (2018) adopted a combination of terrestrial surveying and GPS for the re-observation and re-confirmation of control points in Lagos, Nigeria, yielding high accuracy and precise results, thereby showcasing the efficacy of this method in enhancing the accuracy and reliability of spatial data, while emphasizing the importance of meticulous planning and execution of surveys to ensure accurate results. Similarly, Oke and Adebayo (2020) used photogrammetry for the re-observation and re-confirmation of control points in a survey network in Edo State, Nigeria, achieving high accuracy and precision with a mean error of 0.02 meters in the x-coordinates, 0.03 meters in the y-coordinate, and 0.04 meters in the z-coordinate, demonstrating the potential of photogrammetry as an alternative method for control point re-observation/re-confirmation, especially in areas where traditional surveying methods are difficult or impossible to use. This research work focused on the re-observation and confirmation of control points along the Auchì-Afuzè Road in Edo State, Nigeria, using Global Navigation Satellite System (GNSS) technology to ensure the integrity, accuracy, and reliability of the geodetic control network. The objective was to verify the stability of existing control points and re-establish any disturbed or missing ones, leveraging static GNSS techniques supported by Continuously Operating Reference Station (CORS) OTIC-AUCHI and local base stations (FGP/EDY/072 and FGP/EDY/079).

2. Materials and Methods

2.1. Materials and equipment

The following instrument and materials were employed in the execution of this research work:

4 Hi-Target DGPS, Laptop (HP EliteBook 840 G3, 8GB RAM, 500 GB Hard Disk space), Handheld GPS, Compass, Tribrach, Tripod, Measuring tape, Field book/Pen and software such as Hi Target Geomatics Office, AutoCAD Map 2024, QGIS, Microsoft Excel and Microsoft Word.

2.2. Study Area

This research was conducted in Auchì, situated along the Auchì-Afuzè road in Etsako West Local Government Area, Edo State, Nigeria. Geographically, the site lies within the coordinates 7° 03' 19" N to 7° 03' 22" N latitude and 6° 5' 54" E to 6° 15' 59" E longitude. The predominant ethnic group in Auchì is the Etsako, with the main languages spoken being Afemai, Yoruba, and English. Auchì serves as a significant commercial and industrial hub in Edo State, boasting a thriving market and manufacturing sector. The presence of Auchì Polytechnic has also played a crucial role in the town's growth, providing educational opportunities for students from Auchì and beyond.

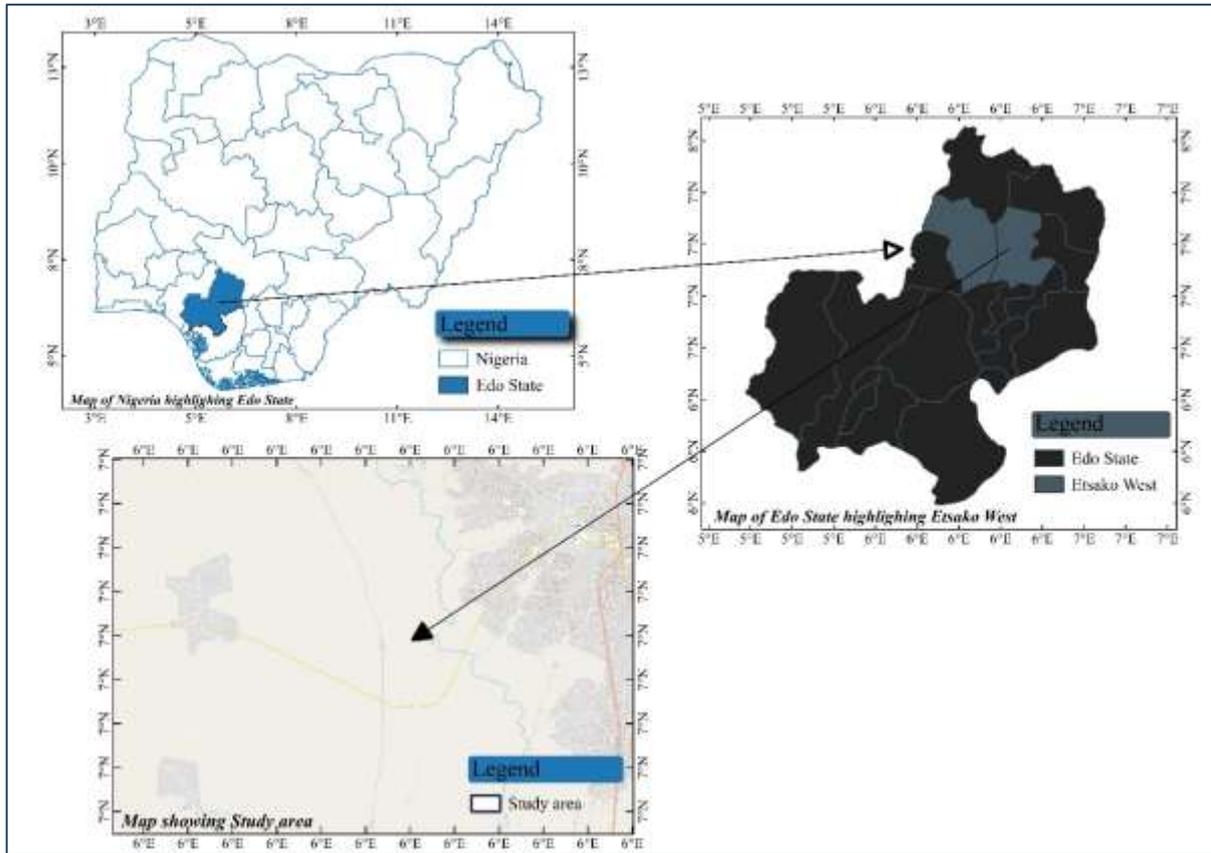


Fig 2.0 Map showing area covered.

2.3. Acquisition of data

GPS data were collected and recorded from network of receivers within the studied area. These data were collected for the defined duration and stored. The process for the collection of data for this study involved static observations using a dual-frequency GPS receiver. Subsequent post-processing was done using FGP/EDY/072, FGP/EDY/079 and OTIC-AUCHI base stations, some of the activities done included baseline adjustment, processing, and comparison of coordinates with different system.

2.4 Analysis of data

Raw GNSS observation were downloaded and converted into RINEX format for the purpose of compatibility. Baseline processing was also ensured for the purpose of establishing correct relative points. This was then compared with 2022 data set for detecting discrepancies in positions (FGP/EDY/072 and FGP/EDY/079).

2.5. Data processing

Raw observation files were downloaded directly from CORS static and GNSS receiver. They were then converted into RINEX format so as to ensure their compatibility the software for post processing. This was followed by a baseline processing for the determination of the specific relative positions of the control points. The network was gradually adjusted for refining the coordinates effectively.

2.6 Procedure for reconnaissance

Visual inspection of the area of interest was first done. Preliminary data on the studied area were collected using reports, maps and secondary sources. The coordinates of the control points were carefully organized.

3. Results and discussion

Table 3.1: Coordinates for control points re-observed

| Station ID | Northings(m) | Eastings(m) | ELEV | Location |
|------------|--------------|-------------|---------|--------------------------------------|
| AME032A | 780789.060 | 196535.428 | 184.268 | Army Post, Auchu |
| AME033A | 780658.419 | 196441.676 | 185.394 | Auchi college, Auchu |
| AME034A | 780457.293 | 196275.011 | 182.983 | Near Royal brain int'l school, Auchu |
| AME035A | 780258.032 | 196148.574 | 168.482 | Near Rilfald sch. Junction, Auchu |
| AME036A | 779916.013 | 195882.671 | 172.892 | Opposite Razark Bello street, Auchu |
| AME037A | 779281.761 | 187988.539 | 236.470 | Ese primary school, |

| | | | | |
|---------|------------|------------|---------|---|
| AME038A | 779327.814 | 187680.581 | 247.167 | Ibviraro Royal palace, Ibviraro |
| AME039A | 779961.786 | 187777.651 | 258.759 | Ibviaro, secondary school, Ibviaro |
| AME040A | 778996.246 | 182292.658 | 193.856 | Ihievbe Pry sch, Ihievbe Afuwadia road junction, |
| AME041A | 778751.214 | 181998.505 | 189.611 | Ihievbe |
| AME042A | 778533.448 | 181889.549 | 189.359 | Grammer school road, Ihievbe |
| AME043A | 778555.252 | 181799.613 | 196.444 | Ihievbegrammer School, Ihievbe |

3.1 Field Reconnaissance

This involves physically visiting the research site to gather firsthand information about the terrain, existing features, control points, and other site conditions. The visit serves to validate the findings from the office reconnaissance and collect additional data required for the study. Control points obtained from the Ministry of Lands and Surveys, along with other identified points, were located using a handheld GPS to confirm their physical existence before beginning data observation. Additionally, a reconnaissance diagram was prepared.

Table 3.2: Existing controls coordinates

| CONTROL ID | EASTING (m) | NORTHING (m) | HEIGHT | LOCATION |
|-------------|-------------|--------------|---------|---|
| OTIC-AUCHI | 198025.796 | 780685.888 | 239.606 | Admin Block, School of Environmental Studies, Area 3, Auchi Poly Auchi. |
| FGP/EDY/072 | 198513.794 | 782022.800 | 199.974 | Akpekpe Primary Sch, Igbe road, Auchi |
| FGP/EDY/079 | 183153.028 | 782378.021 | 244.996 | Osamaran Primary Sch. Ihievbe |
| FGP/EDY/081 | 193501.970 | 788014.932 | 214.693 | Along Army barrack road, Auchi |

NOTE: OTIC-AUCHI projection is on WGS84/UTM ZONE 32N, while the other two controls are in MINNA/UTM ZONE 32N

3.3 Control verification (in situ check)

The coordinates of the existing reference control points were verified as part of the quality assurance process to determine whether they had maintained their original positions since their last observation. This step was critical in assessing the long-term stability and reliability of the control network. FGP/EDY/0 was set as the base and FGP/EDY/072 and FGP/EDY/079 was the rover point, each control point was observed for 2hrs in static mode (table 3).

Table 3. 3: control verification

| Base station | Station Name | | Northings | Eastings | | Height | | | |
|--------------|---------------------|------------|------------|---------------------|-----------|------------|--------|-------|--------|
| | FGP/EDY/081 | | 193501.970 | 788014.932 | | 214.693 | | | |
| Station | Existing coordinate | | Height | Observed coordinate | | Difference | | | |
| | Northings | Eastings | Height | Northing | Eastings | Height | ΔN | ΔE | ΔH |
| FGP/EDY/072 | 782022.800 | 198513.794 | 199.974 | 782022.806 | 198513.8 | 199.849 | 0.006 | 0.003 | -0.125 |
| FGP/EDY/079 | 782378.021 | 183153.028 | 244.996 | 782378.016 | 183153.04 | 244.797 | -0.005 | 0.010 | -0.199 |

The comparison of existing and observed coordinates for FGP/EDY/072 and FGP/EDY/079 shows excellent horizontal stability, with shifts within ±0.01 m. Vertical differences were slightly larger, at -0.125 m and -0.199 m respectively, but still within acceptable limits. These results confirm that the control points remain reliable, though periodic elevation checks are recommended.

3.4 Station description

To facilitate easy identification and access to the control points for future users, a comprehensive documentation of the established stations was compiled. This documentation included detailed information on the location of each station, such as the bearing and distance from a reference point, as well as the relative position to adjacent stations. To ensure accuracy, the measurements were taken using a combination of tools, including a handheld GPS device, a compass, and a measuring tape.

3.5 Downloading Raw Data from Receiver

To download raw GNSS data static data from the receiver, the receiver was first connected to the computer using the appropriate USB cable. Once connected and powered on, after successful connection, browse to the internal storage of the receiver using file

explorer to locate the required survey data, typically found under folders such as "Survey" or "Static." The relevant session files are then selected and downloaded to the computer in their original Hi-Target raw format.

3.6 Editing Point Information

After importing the RINEX static files into Hi-Target Geomatics Office, the next step involved editing and verifying the point information to ensure accuracy. Each observation file was opened within the software, and the station details such as point name, antenna type, antenna height, and occupation time were checked carefully against the field logs. If any station name appeared incorrectly or if the antenna height was missing or wrong, it was edited directly in the point information window provided by the software. The antenna height was entered precisely, distinguishing between slant height or vertical height depending on the method used in the field. Additionally, the correct antenna model was selected from the database to allow the software to apply the proper phase center offset. After all entries were reviewed and corrected where necessary, the updated information was saved, ensuring that the subsequent baseline processing would use clean and verified data without introducing errors from wrong field parameters.

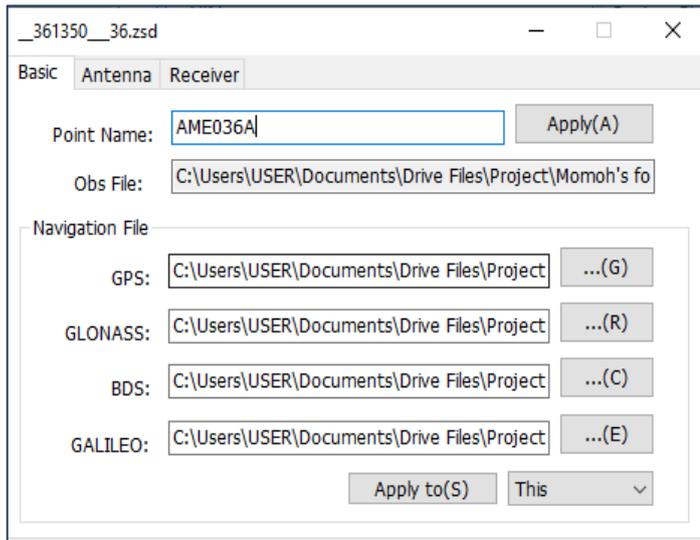


Fig 3.3a: Editing Point Name

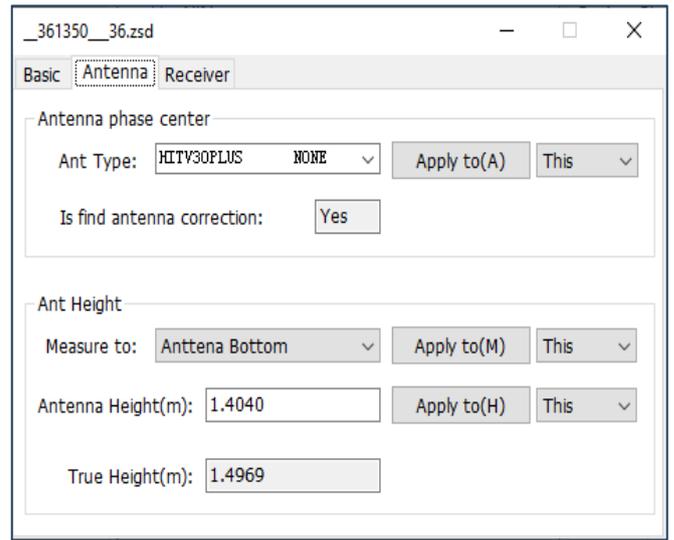


Fig 3.3b: Inputting Antenna Height

3.7 Processing Baseline

After verifying point information and setting control point, the next stage involved processing the baselines between the observed stations. In Hi-Target Geomatics Office, click on baseline and click on Process baseline. The software automatically identified possible baselines between pairs of stations based on the observation sessions. Processing parameters such as satellite elevation mask, signal-to-noise ratio cutoff, and solution method (fixed or float) were configured to optimize accuracy. The software then computed the baseline vectors by resolving carrier phase ambiguities and applying differential corrections to eliminate errors such as atmospheric delay and satellite clock drift. Once processing was completed, each baseline result was reviewed carefully, checking key quality indicators like RMS error, ambiguity resolution success, and the ratio factor. Only baselines that met the required precision standards were accepted, while those with poor quality were re-examined for possible reprocessing or adjustment. Successful baseline processing ensured that the network was strong, reliable, and ready for final network adjustment.

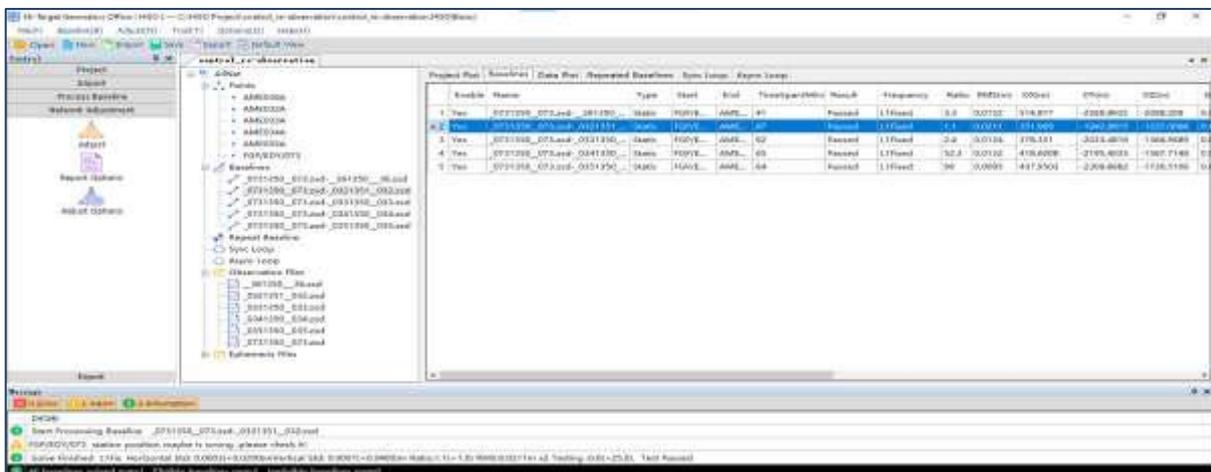


Fig 3.4: Baseline Process result

3.8 Cleaning Bad Signal and Re-Processing Baseline

During the baseline processing stage, certain baselines showed poor quality results, often indicated by high RMS errors, unresolved ambiguities, or low ratio values. To address this, a cleaning process was carried out within Hi-Target Geomatics Office. Observation data with bad satellite signals, such as low signal-to-noise ratios or high multipath errors, were identified and excluded from the processing. In some cases, setting a higher satellite elevation mask helped remove low-angle satellites that contributed noise to the measurements. After filtering out the poor-quality data, the affected baselines were reprocessed by running the computation again with the cleaned dataset. This reprocessing improved the ambiguity resolution and reduced the RMS error, leading to more reliable and accurate baseline vectors. Careful cleaning and reprocessing ensured that only high-quality baselines were used in the final network adjustment, preserving the integrity of the survey results.

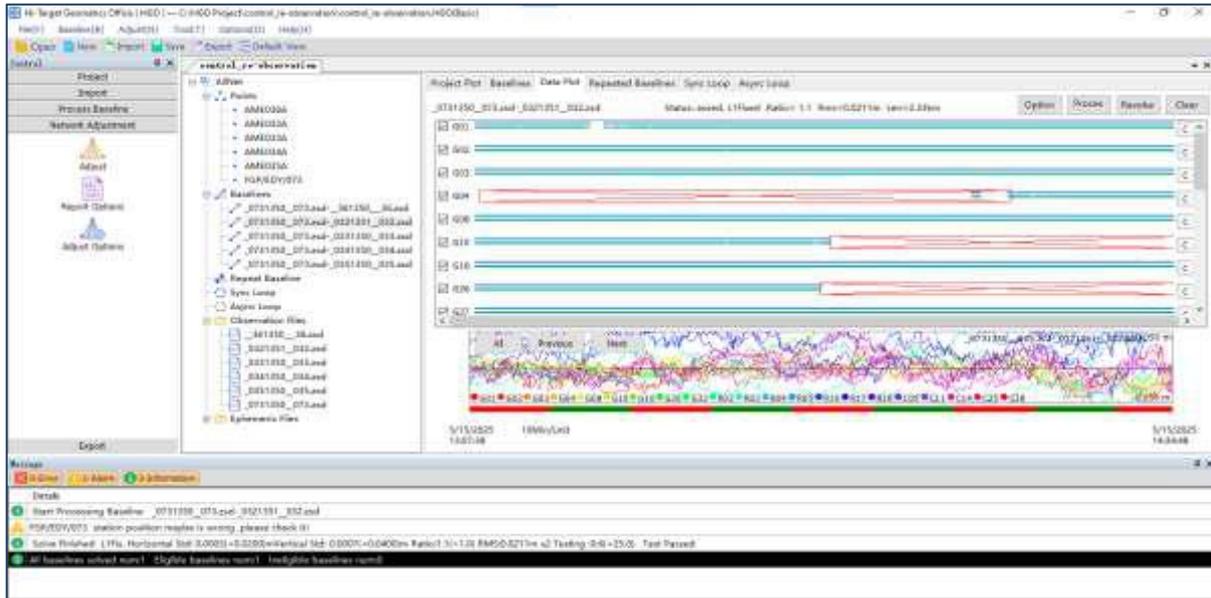


Fig 3.5: Cleaning bad signal

3.9 Exporting Final Coordinate and Report

After completing all adjustments, the final adjusted coordinates from the CORS and local station, and reports were exported. To generate the report, click on Export in the menu bar, select Project File, then choose the desired extension. For the adjusted control points, select Obs-file, choose the .csv extension, and click OK. The final coordinates were exported both Minna datum and wgs 84 datum for both local base (fgp/edy/072 and fgp/edy/079) and CORS (OTIC-AUCHI)

Table 3.4: Adjusted Coordinate in Minna datum

| Station ID | Easting (m) | Northings (m) | Height | Location |
|------------|-------------|---------------|---------|---------------------------------------|
| AME032A | 196535.442 | 780789.072 | 183.899 | Army Post, Auchi |
| AME033A | 196441.666 | 780658.432 | 185.083 | Front of Auchi college, Auchi |
| AME034A | 196275.023 | 780457.285 | 182.618 | Royal brain int'l school, Auchi |
| AME035A | 196158.09 | 780295.459 | 169.353 | Near Rilfald sch. Junction, Auchi |
| AME036A | 195888.871 | 779925.952 | 171.962 | Opposite Razark Bello street, Auchi |
| AME037A | 187988.526 | 779281.773 | 236.428 | Ese primary school, Ibviraro |
| AME038A | 187680.579 | 779327.814 | 247.279 | Bike Park, Ibviraro |
| AME039A | 187777.640 | 779961.795 | 258.779 | Ibviaro secondary school, Ibviaro |
| AME040A | 182293.664 | 778996.294 | 193.885 | Front of Ihievbe Pry Sch, Ihievbe |
| AME041A | 181998.507 | 778751.228 | 189.731 | After Afuwadia road junction, Ihievbe |
| AME042A | 181889.396 | 778533.426 | 189.242 | Grammar school road, Ihievbe |
| AME043A | 181799.604 | 778555.253 | 196.734 | Ihievbe Grammar School, Ihievbe |

4. Data Analysis

After post-processing the observed raw data, the next step was to compare the results with those obtained in 2022. This comparison helps determine the current state of the controls and detect any shifts caused by natural or man-made disturbances. The difference between the two observations can be mathematically expressed as:

$$\Delta = d_{2025} - d_{2022}$$

Where: Δ = Change or shift detected

d_{2025} = Current (post-processed) coordinate or measurement in 2025

d_{2022} = Previous coordinate or measurement in 2022

A significant Δd indicates a possible displacement or deformation of the control points.

Table 4.1: Coordinate Comparison

| Station ID | 2022 Coordinates (d2022) | | | 2025 Coordinates (d2025) | | | Difference (Δ) | | |
|------------|--------------------------|---------------|------------|--------------------------|---------------|------------|-------------------------|------------|------------|
| | Easting (m) | Northings (m) | Height (m) | Easting (m) | Northings (m) | Height (m) | ΔE | ΔN | ΔH |
| AME032A | 196535.4 | 780789.1 | 184.268 | 196535.4 | 780789.1 | 183.899 | 0.014 | 0.012 | - |
| AME033A | 196441.7 | 780658.4 | 185.394 | 196441.7 | 780658.4 | 185.083 | -0.01 | 0.013 | - |
| AME034A | 196275 | 780457.3 | 182.983 | 196275 | 780457.3 | 182.618 | 0.012 | - | - |
| AME035A | 196148.6 | 780258 | 168.482 | 196148.6 | 780258 | 168.353 | 0.005 | 0.017 | - |
| *AME036 | 195882.7 | 779916 | 172.892 | 195888.9 | 779926 | 171.962 | 6.2 | 9.939 | -0.93 |
| AME037A | 187988.5 | 779281.8 | 236.47 | 187988.5 | 779281.8 | 236.428 | - | 0.012 | - |
| AME038A | 187680.6 | 779327.8 | 247.167 | 187680.6 | 779327.8 | 247.279 | - | 0 | 0.112 |
| AME039A | 187777.7 | 779961.8 | 258.759 | 187777.6 | 779961.8 | 258.779 | - | 0.009 | 0.02 |
| AME040A | 182292.7 | 778996.2 | 193.856 | 182293.7 | 778996.3 | 193.885 | 0.006 | 0.048 | 0.029 |
| AME041A | 181998.5 | 778751.2 | 189.611 | 181998.5 | 778751.2 | 189.731 | 0.002 | 0.014 | 0.12 |
| AME042A | 181889.5 | 778533.4 | 189.359 | 181889.4 | 778533.4 | 189.242 | - | - | - |
| AME043A | 181799.6 | 778555.3 | 196.444 | 181799.6 | 778555.3 | 196.734 | - | 0.001 | 0.29 |

AME036A was re-established

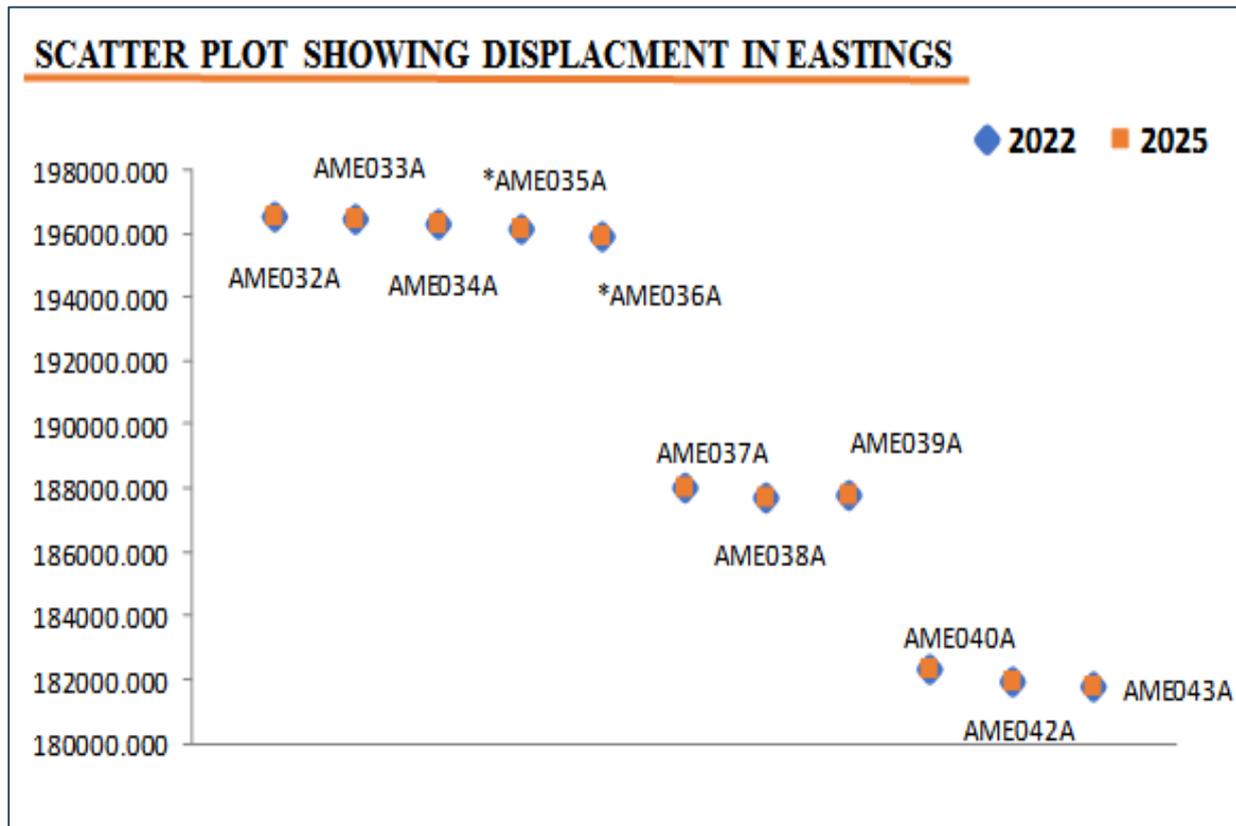


Fig 4.1: Scatter plot showing Displacement in Eastings

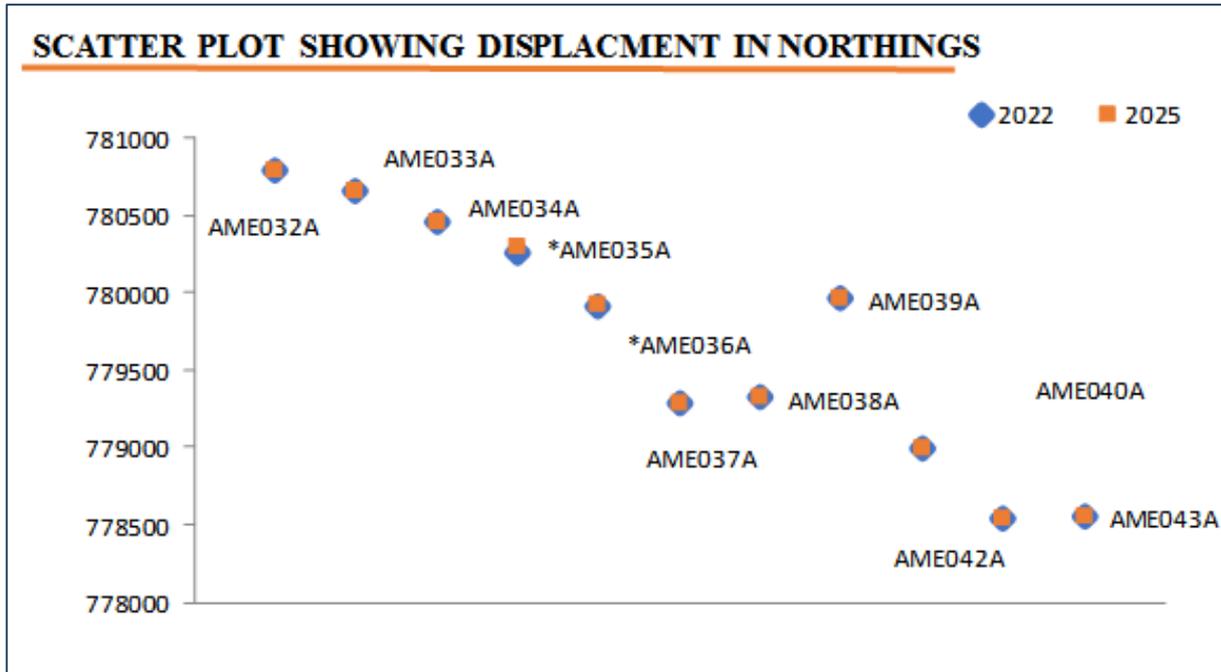


Fig 4.2: Scatter plot showing Displacement in Northings

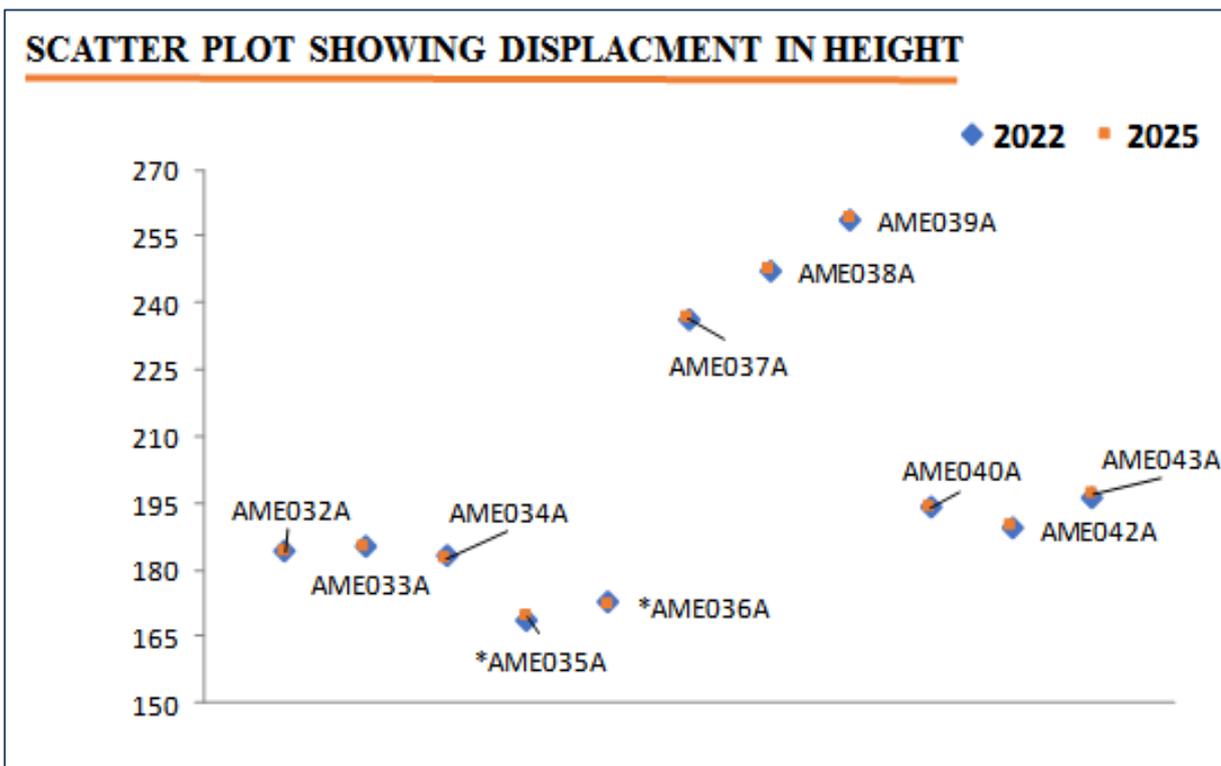


Fig 4.3: Scatter plot showing Displacement in Height

The coordinate comparison in Table 4.1 presents an analysis of positional changes between data observed in 2022 and re-observed in 2025, both referenced to the Minna datum (Clarke 1880 RGS ellipsoid). This analysis was aimed at assessing the stability of control points over the three-year period and identifying any significant shifts in Eastings, Northings, and Heights. The difference (Δ) in coordinates was computed using the formula $\Delta = d_{2025} - d_{2022}$, where d_{2025} represents the updated 2025 observation and d_{2022} the original 2022 data. The majority of the control points exhibited minimal variations, with Easting and Northing shifts generally less than ± 0.02 m and vertical differences within ± 0.4 m, which is indicative of good positional consistency and stable monumentation. However, a notable exception is observed at station *AME036A, which recorded a significant shift of 6.200 m in Easting, 9.939 m in Northing, and -0.930 m in height. This substantial difference is expected, as the station was re-established in 2025, leading to positional displacement relative to its original location. Slight deviations at other points, such as AME040A and AME042A, may be attributed to minor field conditions, measurement errors, or environmental interference. Overall, the

comparison confirms that most of the network remained stable between 2022 and 2025, and the transformation procedures and post-processing workflows applied during the 2025 re-survey were effective in preserving spatial accuracy.

Figure 4.10 highlights displacement in height, where greater variability is observed. Stations such as AME039A, AME040A, and AME043A show noticeable vertical displacement, which may be attributed to instrument sensitivity, environmental factors, or benchmark disturbance. In summary, both the tabular and graphical analyses confirm that the control network remained largely stable over the observation period, with exceptions accounted for by intentional re-establishment or localized vertical changes.

5. Conclusion and Recommendations

This research work successfully demonstrated the application of static GNSS surveying techniques for the re-observation and validation of geodetic control points along the Auchì–Afuze Road corridor in Edo State, Nigeria. Using a combination of fixed control stations, CORS data, and post-processing with Hi-Target Geomatics Office, the project achieved its objective of confirming the positional stability of the existing network and updating any disturbed or missing stations. The coordinate comparisons between 2022 and 2025 observations showed that the majority of the control points maintained high positional consistency, with only minimal variations observed in Eastings, Northings, and Heights. The exception, AME036A, which was re-established, presented a notable shift, confirming the necessity of re-validation and field inspection in areas of infrastructural change.

Based on the experiences and findings of this research work, it is recommended that established control points be periodically re-observed and maintained to prevent degradation or displacement due to construction, erosion, or natural events. Also, future projects requiring precise height data should incorporate local geoid models to convert ellipsoidal heights to orthometric heights.

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