Evaluating the Impact of the Fourmil Standard Meridian on Cadastral Survey Accuracy in Modern Surveying Techniques: A Case Study in PNG UoT, Lae Morobe, PNG

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Abstract

The establishment of the Fourmil Standard Meridian in Papua New Guinea has had a significant impact on the accuracy of cadastral surveys in the region. This study examines the effects of this meridian on modern surveying techniques, with a focus on its influence on the quality and reliability of spatial cadastral data. Through a case study approach, the research investigates the challenges and opportunities presented by the Fourmil Standard Meridian, analysing its influence on boundary delineation, parcel identification, and spatial data integration. The findings provide insights into the importance of understanding the historical context and spatial infrastructure in improving the overall cadastral system and supporting land tenure security in developing countries. This study evaluates the impact of the Fourmil Standard Meridian on the accuracy of cadastral surveys in modern surveying techniques, with a specific focus on Papua New Guinea (PNG). The Fourmil Standard Meridian serves as a critical reference for angular measurements in surveying, influencing the precision of land boundary definitions. The research highlights the integration of advanced surveying technologies, such as Real-Time Kinematic (RTK) Global Positioning System (GPS) and Unmanned Aerial Vehicles (UAVs), which have significantly enhanced the accuracy and efficiency of cadastral surveys. In PNG, where land tenure issues are often complex and contentious, the application of these modern techniques is essential for effective land administration and conflict resolution. The study further discusses the Fit-for-Purpose Land Administration (FFPLA) approach, which emphasizes adaptable and cost-effective land management systems. By leveraging contemporary surveying methods within this framework, stakeholders can improve the maintenance and updating of cadastral data, thereby securing land rights and promoting sustainable development. The findings underscore the importance of the Fourmil Standard Meridian in conjunction with modern surveying technologies in addressing the challenges of land administration in PNG.

Keywords: *Cadastral survey, Land Administration, Modern surveying techniques, Real-Time Kinematic GPS, Unmanned Aerial Vehicles.*

1. Introduction

Recent advancements in surveying technologies, such as Real-Time Kinematic (RTK) Global Navigation Satellite Systems (GNSS), and Unmanned Aerial Vehicles (UAVs), have transformed the landscape of cadastral surveying. RTK GNSS provides high-precision positioning, achieving accuracies of approximately 11 mm horizontally and 34 mm vertically, which is crucial for delineating property boundaries (Kizil et al., 2006; Scherzinger, B 2006). The integration of RTK GNSS with the Fourmil Standard Meridian (FSM) enhances the reliability of cadastral surveys, allowing for consistent and accurate land measurements that can be referenced against the standard meridian. This is particularly relevant in PNG, where traditional surveying methods may be inadequate due to challenging terrain and limited infrastructure (Boey & Parker, 1996). UAV technology has also emerged as a powerful tool for cadastral mapping. UAVs can efficiently cover large areas, capturing high-resolution imagery that can be processed to create accurate orthophotos and 3D models of the terrain (Stöcker et al., 2020; Yuwono et al., 2018). This capability is especially beneficial in remote regions of PNG, where access may be limited. The combination of UAV data with GNSS positioning not only improves the accuracy of cadastral surveys but also facilitates the rapid updating of land records, which is essential in a dynamic land tenure environment (Stöcker et al., 2022). Moreover, the concept of Fit-for-Purpose Land Administration (FFPLA) emphasizes the need for adaptable and cost-effective surveying methods that can address the unique challenges faced in different regions, including PNG. FFPLA advocates for the use of modern technologies to streamline the cadastral process, thereby reducing costs and time while improving the accuracy of land records (Kelm et al., 2021). This approach aligns well with the FSM, as it allows for the integration of various surveying techniques to enhance the overall effectiveness of land administration systems. The Fourmil Standard Meridian is a reference point used in surveying, providing a fixed geographic coordinate system for the measurement and mapping of land parcels. This meridian, which is based on the International Terrestrial Reference Frame, serves as a basis for the delineation of property boundaries and the determination of land ownership rights (Chio & Chiang, 2020).

The advent of advanced surveying technologies has transformed the landscape of cadastral surveying. Techniques such as Real-Time Kinematic (RTK) Global Positioning System (GPS) and Unmanned Aerial Vehicles (UAVs) have emerged as powerful tools that enhance the accuracy and efficiency of land boundary delineation. RTK GPS allows surveyors to achieve high levels of positional accuracy, often within centimeters, thereby reducing uncertainties associated with traditional surveying methods (Kizil et al., 2006). UAVs, on the other hand, provide rapid data acquisition capabilities, enabling the generation of high-resolution aerial imagery that can be processed to define property boundaries with remarkable precision (Mesas-Carrascosa et al., 2014). These technological advancements are particularly relevant in PNG, where challenging terrain and logistical constraints often impede traditional surveying efforts.

The significance of accurate cadastral surveys extends beyond mere boundary delineation; it is crucial for effective land governance and conflict resolution. In PNG, land disputes are common, often arising from overlapping claims and unclear boundaries. By employing modern surveying techniques that leverage the Fourmil Standard Meridian, stakeholders can enhance the reliability of cadastral data, thereby facilitating the resolution of disputes and the establishment of secure land rights. Furthermore, the Fit-for-Purpose Land Administration (FFPLA) approach, which emphasizes the need for adaptable and cost-effective land management systems, aligns well with the capabilities of these modern surveying technologies (Antonio et al., 2021; Balas et.al, 2021; Enemark et. al, 2021; Musinguzi et.al, 2021; Tchatchoua et. al, 2020; Wilcox, D, 1984). FFPLA advocates for the provision of secure land rights at scale, addressing the challenges faced in rapidly urbanizing areas and ensuring that land administration systems are responsive to the needs of local communities.

This introduction sets the stage for a comprehensive evaluation of the Fourmil Standard Meridian's impact on cadastral survey accuracy in PNG, highlighting the interplay between traditional surveying principles and modern technological advancements. The subsequent sections of this study will delve into the methodologies employed, the results obtained, and the implications for land administration practices in PNG.

In Papua New Guinea (PNG), the accuracy of cadastral surveys is critical for effective land administration, particularly given the complexities of land tenure systems that often involve customary land rights and overlapping claims. The Fourmil Standard Meridian, which serves as a reference for angular measurements in surveying, is essential for ensuring the precision of land boundary delineation. However, the traditional methods of cadastral surveying may not adequately address the challenges posed by the unique geographical and socio-political landscape of PNG. Modern surveying techniques, such as Real-Time Kinematic (RTK) Global Positioning System (GPS) and Unmanned Aerial Vehicles (UAVs), have the potential to significantly enhance the accuracy and efficiency of cadastral surveys. Despite the availability of these advanced technologies, their integration into existing land administration practices in PNG remains limited. This raises critical questions regarding the effectiveness of the Fourmil Standard Meridian in conjunction with these modern techniques and how they can be leveraged to improve cadastral survey accuracy.

The main objectives of the current study are to; assess the role of the Fourmil Standard Meridian in modern cadastral surveying techniques, evaluate the accuracy of RTK GPS and UAVs in cadastral surveys within the context of PNG, and Analyze the implications of improved cadastral survey accuracy for land administration and conflict resolution in PNG. By addressing these objectives, the study aims to contribute to the body of knowledge on land administration in PNG and provide practical recommendations for integrating modern surveying technologies into existing frameworks.

The study aims to evaluate the impact of the Fourmil Standard Meridian on the accuracy of cadastral surveys utilizing modern surveying techniques, specifically in the context of Papua New Guinea (PNG). The scope of the research encompasses around the following key areas as technological Integration, cadastral Survey Accuracy, land Administration and Conflict Resolution, and geographical Focus. The significance of this study lies in its potential to address critical issues surrounding cadastral survey accuracy and land administration in Papua New Guinea (PNG). Accurate cadastral surveys are essential for establishing clear land boundaries, resolving disputes, and securing land rights, particularly in a context where customary land tenure systems prevail (Priti et. al, 2009).

The study is important not only for its potential to improve cadastral survey accuracy in PNG but also for its broader implications for land governance, conflict resolution, and sustainable development. By addressing these critical issues, the research can contribute to the establishment of secure land rights and promote effective land administration practices in PNG. Despite the advantages of modern surveying techniques, challenges remain in their implementation. Any new parcels must be accurately fitted and aligned with existing ones, necessitating a spatial adjustment approach to improve accuracy over time (Pullar & Donaldson, 2022). Additionally, the integration of these technologies into existing land administration frameworks requires careful consideration of technical, logistical, and regulatory factors (Bennett et al., 2021). The literature suggests that ongoing research and development in UAV technology, RTK GPS, and automated feature extraction will continue to enhance cadastral survey accuracy. As these technologies evolve, they hold the potential to bridge the gap between traditional surveying methods and the demands of modern land administration systems(Trung et al., 2021; Luo et. al, 2017a,b). The continuous improvement of these methodologies will be crucial for addressing the challenges of land tenure and governance, particularly in developing countries.

These studies have demonstrated the suitability of UAV-based photogrammetry for cadastral applications, particularly in the context of coastal areas where traditional ground-based survey methods may be challenging. (Sim & Song, 2018; Yuwono et al., 2018). The Fourmil Standard Meridian is particularly relevant when integrated with modern surveying technologies such as Real-Time Kinematic (RTK) GPS and Unmanned Aerial Vehicles (UAVs). These technologies enhance the accuracy of measurements and allow for real-time data collection, which can be aligned with the Fourmil Standard Meridian to ensure consistency in land boundary definitions (Kizil et al., 2006). The combination of these advanced technologies with the Fourmil Standard Meridian can significantly improve the quality of cadastral data and facilitate more effective land administration practices.

2. Methodology

2.1 Data Collection and Processing

The study employs a mixed-method approach, combining quantitative and qualitative data collection methods to evaluate the impact of the Fourmil Standard Meridian on cadastral survey accuracy. The research design includes a case study at PNG UOT in Lae Morobe, PNG. Field surveys were conducted using modern surveying equipment, such as Total Stations, GNSS receivers and UAV drones were used to collect cadastral data. The surveys were conducted at various points within the study area to capture a representative sample. Survey data was collected using the reference stations CS 44 and PSM 3374, See table 1 recorded in the survey cadastral file catalogue, file number 31/529. This survey file includes only the bearings and distances, excluding the coordinates. The purpose of conducting this survey is to establish the true ground distance in comparison to GPS and UAV data including comparison to FSM assessments.

Table 1. Collected survey data.

Set up @ CS 44	
RO to PSM 3374	To Station T1
34º13’49’’ (*FR)*	32º21’09’’
214º14’07’’/+18’’*(FL)* =34º13’49’’	212º27’52’’/121/2/61-18’’ =32º27’43’’
Horizontal Dist – 410.946 m	126.520 m
Vertical Dist – 3.520 m	1.238 m
Slop Dist – 410.961 m	126.526 m

Figure 1 illustrates how the reference marks were obtained using existing survey plans and data. The reference marks were determined by calculating the missing distance and bearing between CS 44 and PSM 3374. The marks available on the plans included those from IP 12 to CS 44 and PSM 3374.

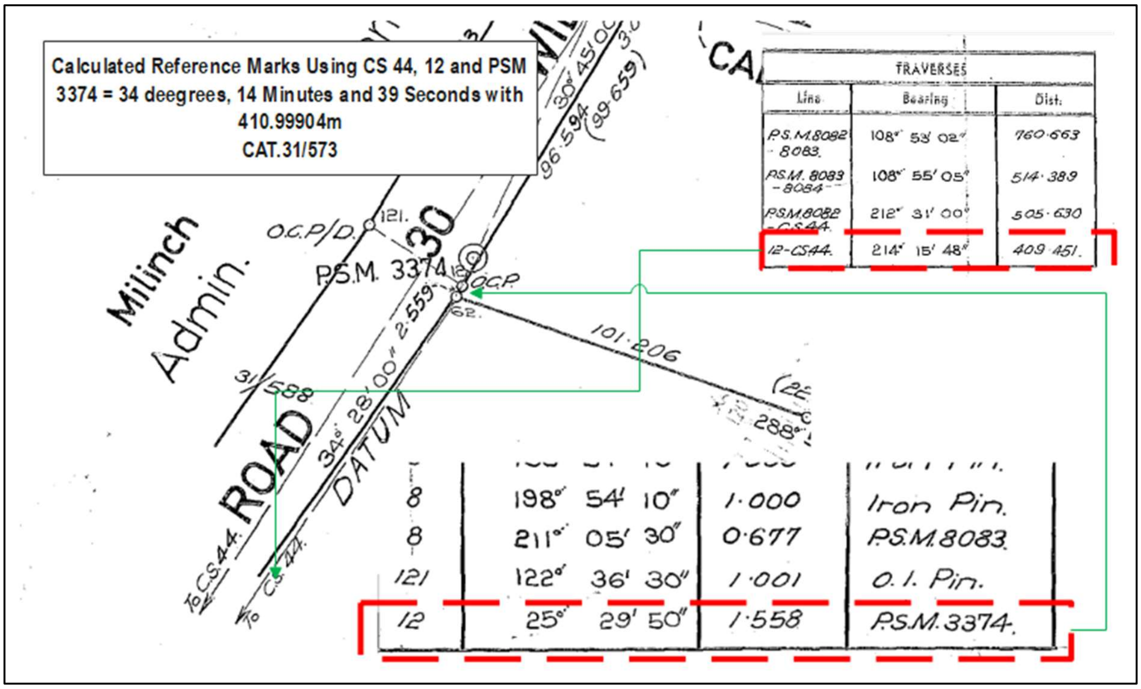

Fig. 1 Reference marks extraction

The survey set-up station using a total station was established at CS 44. Observations were made in reference to PSM 3374, and radiations were conducted to T1, a survey station set up for FSM convergent and comparison.

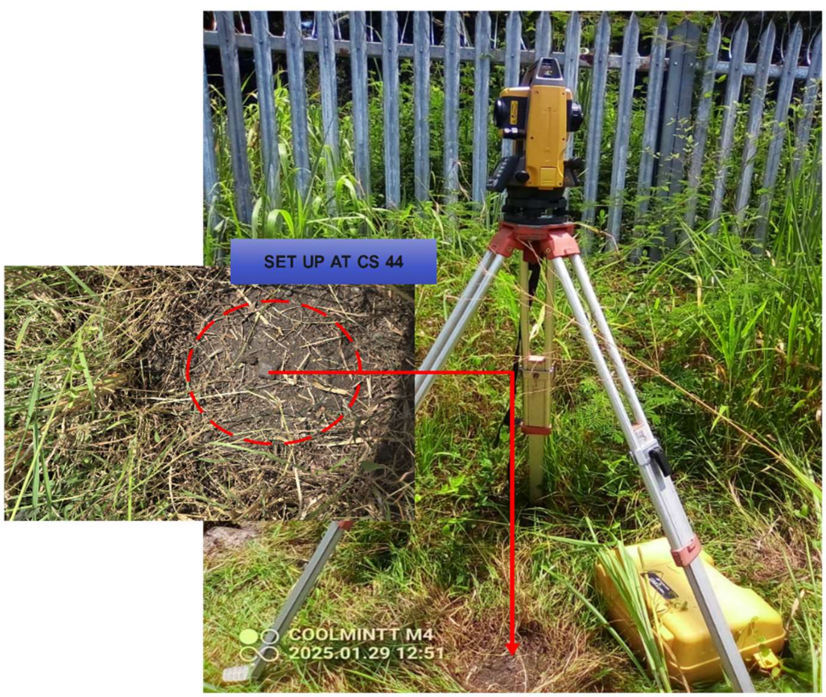

Fig. 2 Data collections by Total Station

The GNSS/GPS data was collected using a Hi-Target V90 Survey Equipment. The GPS was set up on three stations: the Base station at PSM 3374, (table 2 and figure 2) and 30-minute observations were conducted on the two stations T1 and CS 44 using the Precise Point Positioning Mode (PPP) – Static Survey. The collected data was then post-processed using Topcon Magnet Office Software. The table 2 shows the post-processed results of the GNSS GPS data observation without the ground truth scale factor. The scaling of the coordinates will be performed to align the GPS coordinates to match the ground coordinates and distances.

Table 2. Post-processed results of the GNSS GPS data

Name	Grid Northing (m)	Grid Easting (m)	Elevation (m)	Std. Dev. N (m)	Std. Dev. E (m)	Std Dev u (m)	Std Dev Hz (m)	Geoid Separa-tion (m)
PSM 3374	9264040.437	499627.903	70.868	0	0	0	0	72.946
CS44	9263700.12	499397.86	67.65	0.001	0.001	0.002	0.001	72.934
T1	9263807.038	499465.41	68.895	0.002	0.002	0.005	0.003	72.938

Fig. 3 Data collections by GNSS GPS (Global Positioning System)

2.2 Scale Factor

The scale factor is vital when converting GPS coordinates to ground distances or total station data due to the differences in the Earth's curvature and projection systems. GPS coordinates are measured on an ellipsoid, a mathematical model of the Earth's shape, while ground distances and total station data are typically measured in local coordinate systems with different projections. The scale factor reconciles these differences, ensuring measurements are accurate and consistent.

In practical terms, the scale factor allows for seamless integration of GPS data, ground distances, and total station data in large-scale mapping or construction projects. This ensures that all data sources are consistent, accurate, and reliable, providing a cohesive representation of the project's area. Essentially, the scale factor bridges the gap between global and local coordinate systems, making precise and reliable measurements possible.

To apply a scale factor for Total Station observations in relation to GPS observations, the following steps are taken:

2.2.1 Determine the Scale Factor

The scale factor is used to convert grid distances (measured by GPS) to ground distances (measured by the Total Station). The scale factor can be derived from the projection system being used, such as the UTM system. The scale factor was calculated using equations 1 and 2, based on GPS and a Total station, using scaling the grid to ground distance, vice versa for ground distance to grid.

$$K = \frac{\text{GridDistance(by GPS)}}{GroundDistance(by\ Total\ Station)} \tag{1}$$

$$K = \frac{\text{Ground Distance (by Total Station)}}{Grid\ Distance\ (by\ GPS)} \tag{2}$$

Alternatively, if we know the central meridian and coordinates of the point, we can use the following formula:

$$K = 1 + (\frac{\text{h} - \text{ho}}{a}) \tag{3}$$

Where: k = *Scale factor,* h = *Ellipsoidal height of the point,* h_o= *Ellipsoidal height at the central meridian,* a = *Semi-major axis of the ellipsoid.*

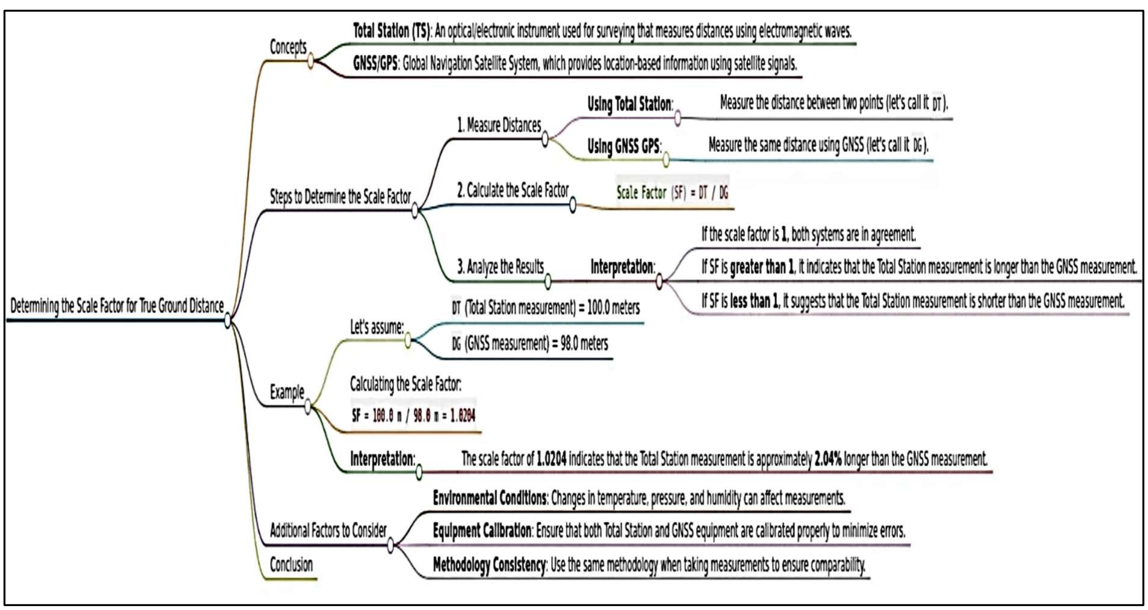

Fig. 4 Scale Factor Determination

2.2.2 Determining the Scale Factor for Total Station and GPS observation

The observation was conducted using both Total Station and GPS static observation methods to determine ground and grid distances, respectively, as shown in Figure 4. The setup was established at CS 44, with observations made to T1 and PSM 3374 for the actual ground distances utilizing the Total Station. Simultaneously, GPS static observation was carried out at the same station using Hi-Target v90 equipment. Figure 5 illustrates the observations made, along with the plotted distance differences used for scale-factor calculation. The combination of Total Station and GPS observations allows for accurate determination and comparison of ground and grid distances, essential for precise mapping and surveying projects. Since the formula for determining the scale factor is the grid distance divided by the ground distance (or vice versa, depending on the scale to apply), the calculation is as follows:

(CS 44 – PSM 3374) GPS Distance/ (CS 44 – PSM 3374) Total Station Distance = 410.774m/410.946m = 0.99958145352431 (k or the scale factor to apply for the GPS coordinates).

Since we will scale the GPS distance to the total station distance, we will apply the inverse of the scale factor: 1/0.99958145352431. Conversely, the scale factor will be used as is for converting ground distance to grid distance.

After calculating the scale factor using the ground distance (Total Station observation) as the base, the scale factor will be applied to the GPS coordinates (Figure 4 and 5). This will determine the approximate distance and coordinates based on the scale factor. The purpose is to align both observations so they can be projected on the same plane, ensuring the accuracy of the true ground distances.

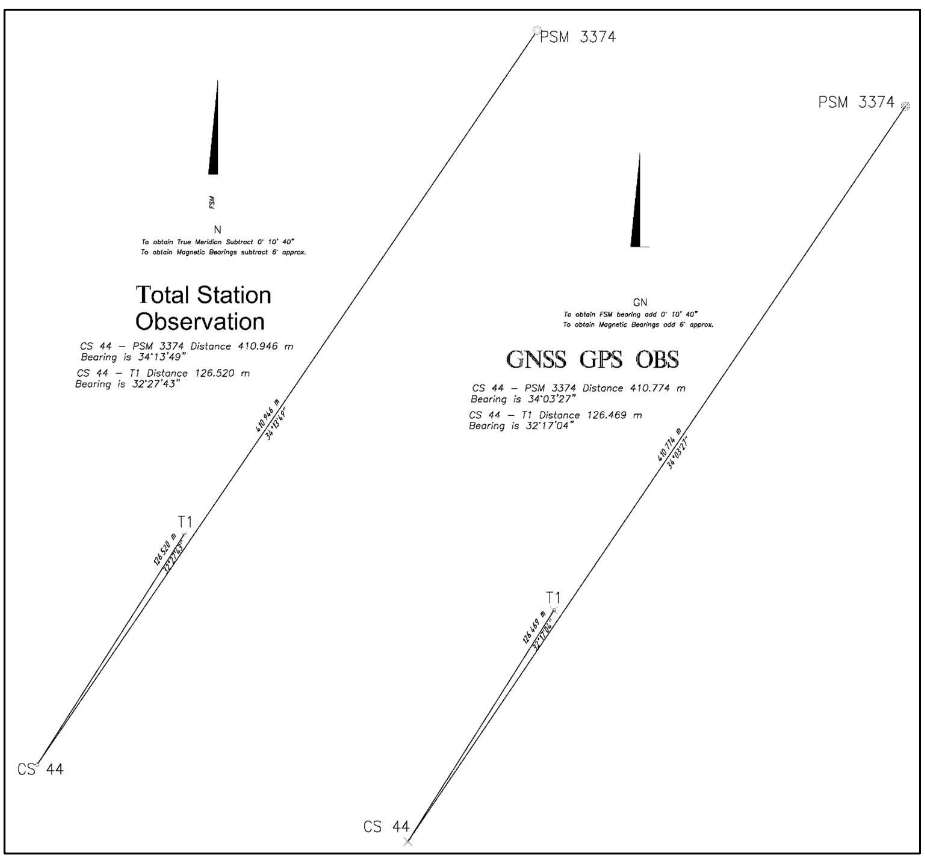

Fig. 5 Comparison between Total Station observation and GNSS GPS observation

2.2.3 Data collection by UAV Drone

After completing the GPS and Total Station fobservations (Figure 2, 3 and 5) for the three marks, PSM 3374, CS 44, and T1, the next step was to conduct a UAV (Unmanned Aerial Vehicle) flight to capture high-resolution aerial images and generate accurate topographic data (Figure 6). The UAV flight was meticulously planned to ensure optimal coverage of the survey area. Prior to the flight, the UAV's GPS system was calibrated using the established coordinates from the Total Station and GPS observations, ensuring precise alignment with the ground control points. The UAV was programmed with a flight path that covered the entire survey area, including the three marks (Figure 6). The flight was conducted at a consistent altitude and speed to capture overlapping images for accurate photogrammetric processing.

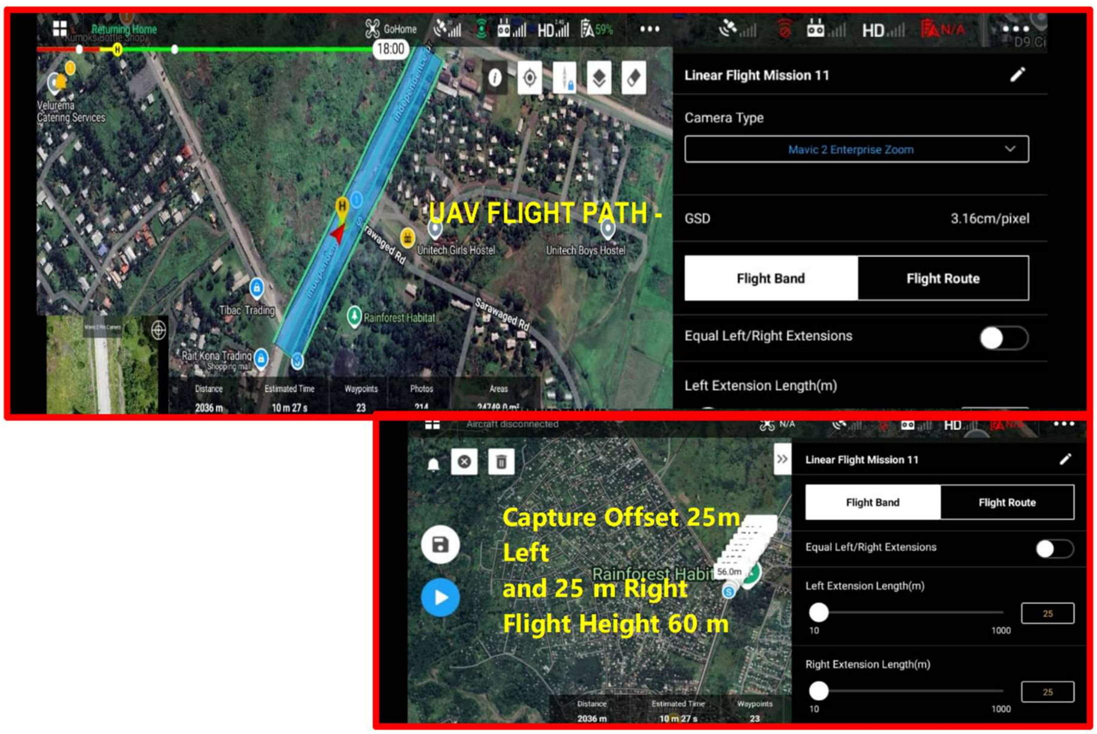

Fig. 6 UAV flight plan and captured data.

Once the UAV flight was completed, the collected aerial images were processed using specialized software to create an orthomosaics and a digital elevation model (DEM) of the survey area. The images were georeferenced using the ground control points from PSM 3374, CS 44, and T1, ensuring accurate spatial alignment. The post-processed data was then compared to the Total Station and GPS observations to validate the accuracy and consistency of the UAV-derived measurements. This comprehensive approach, combining UAV, GPS, and Total Station data, enabled precise mapping and surveying of the area, providing valuable insights for further analysis and decision-making

2.3 Data Analysis

2.3.1 Calculating the Coordinates for CS 44 and PSM 3374 by applying the scale factor for 2D plane Surveying

The bearing and distance measured by the total station for CS 44 and PSM 3374 were compared against the GPS observations for these same stations. The scale factor was then calculated based on this comparison. Subsequently, this scale factor will be applied to the GPS observations in order to derive the exact ground coordinates.

Table 3. Original Coordinates in Meters – (GPS Observation)

Name	Grid Northing (m)	Grid Easting (m)	Elevation (m)
PSM 3374	9264040.437	499627.903	70.868
CS44	9263700.12	499397.86	67.65

Applying Scale Factor

Point A (PSM 3374) (adjusted):

- Northing: 9264040.437×1.0004187217302 ≈ 9267919.492
- Easting: 499627.903×1.0004187217302 ≈ 499837.108

Point B (CS 44) (adjusted):

- Northing: 9263700.12×1.0004187217302 ≈ 9267579.033
- Easting: 499397.86×1.0004187217302 ≈ 499606.969

Table 4. Adjusted scale factor Coordinates in Meters – *(Total Station Observation)*

Name	Ground Northing (m)	Ground Easting (m)	Elevation (m)
PSM 3374	9267919.492	499837.108	70.868
CS44	9267579.033	499606.969	67.65

Calculate the Euclidean Distance to do fine corrections and confirmations of the distance between CS 44 & PSM 3374.

The formula to calculate the Euclidean distance between two points is given in equation 4.

$$D = \sqrt{(E_B - E_A)^2 + (N_B - N_A)}^2 \quad (4)$$

Substitute the given values into the formula:

$$D = \sqrt{(499606.969 - 499837)^2 + (9267579.033 - 9267919.492)^2} \quad (5)$$

Calculate the differences:

$$D = \sqrt{(-230.139)^2 + (-340.459)^2} \quad (6)$$

The Euclidean Distance between CS 44 – PSM 3374 was 410.946 m (Corrected from GPS Distance to Ground Distance) - This is similar to the observation made with the Total Station.

The slight changes in coordinates ensure the distances between points align correctly with the intended coordinate system or measurement method. By applying the scale factor, we can correct for discrepancies between GPS and Total Station measurements, ensuring accurate and consistent data.

2.3.2 Earth Curvature Correction for the Euclidean Distance between CS 44 & PSM 3374

The curvature correction (Cc) is calculated using the formula:

$$C_C = \frac{D^2}{2R} \quad (7)$$

Where:
C_c = Curvature Correction
D = Distance (410.946 meters)
R = Radius of the Earth (approximately 6,371,000 meters)
Calculate the correction: $C_C = \frac{410.946^2}{2(6371000)}$ = 0.013253 meters

Adjusting the distance: Combine the Euclidean distance and the curvature correction: $D_{corrected} = D - C_c$ = 410.933 meters

2.3.3 Earth's Atmospheric Correction for the two stations CS 44 & PSM 3374

Atmospheric corrections include ionospheric and tropospheric corrections. For simplicity, let's focus on tropospheric correction using the *Saastamoinen model*:

Tropospheric Correction Formula

$$\Delta_{\text{tropo}} = 2.3 \text{ x } 10^{-4} \frac{\text{P}}{\text{T} + 273.15}$$

Where:
Δ_{tropo} = Tropospheric delay in meters
P = Atmospheric pressure in hPa (Assume 1013hPa)
T = Temperature in ^{0}C (Assume 25^{0}C)

$$\Delta_{\text{tropo}} = 2.3 \text{ x } 10^{-4} \frac{1013}{25 + 273.15} = 0.0072$$

2.3.4 Distance Calculation

Combine the curvature correction and atmospheric correction with the Euclidean distance: $D_{Final} = D_{Corrected} - \Delta_{tropo}$ = 410.933 m – 0.0072 m = 410.9258 meters (D_{C44} & $D_{PSM\ 3374}$)

2.3.5 Adjusted Coordinate, including Curvature correction, Atmospheric Correction, and Grid distance to Ground.

The final adjusted coordinates for CS 44 and PSM 3374 after all corrections was done using the scale of the final Distance calculation after earth curvature correction, atmospheric corrections and grid to ground distance corrections. The final distance after all corrections was divided by the grid to ground distance correction; 410.9258m/410.946m = 0.9999508451 the final scale factor.

The final coordinates for CS 44 and PSM 3374 are shown in table 5. They were found after all the necessary changes were made to a flat 2D surface, including fixing the earth's curvature and the atmosphere, and converting the grid-to-ground distance.

Table 5. Adjusted coordinates.

Name	Ground Northing (m)	Ground Easting (m)	Elevation (m)
PSM 3374	9267463.929	499812.538	70.868
CS44	9267123.486	499582.411	67.65

3. Results and Findings

The analysis of the GPS and Total Station data for points PSM 3374 and CS 44 revealed insightful findings. Initial calculations of the Euclidean distance between the points indicated a distance of approximately 410.946 meters. This distance was then adjusted to account for the Earth's curvature, resulting in a corrected distance of approximately 410.933 meters. Further refinement was achieved by applying atmospheric corrections, specifically addressing tropospheric delays, which adjusted the final distance to approximately *410.9258 meters*.

However, when comparing these GPS-derived distances with the Total Station measurement of 410.946 meters, a slight discrepancy was noted. This difference, though minimal, can be attributed to several factors, including measurement accuracy, atmospheric effects, projection distortions, and potential instrument calibration errors. Applying a scale factor to the GPS data helped align the measurements, demonstrating the importance of considering such corrections in geodetic practices.

Overall, the results underscore the significance of meticulous data adjustment and correction processes in achieving consistent and accurate measurements. The study highlights the need for combining multiple correction factors to mitigate discrepancies and ensure reliable geospatial data for practical applications.

The plain distance on the ground, often called the "ground distance," is not always the same as the "grid distance". The analysis of points CS 44 and PSM 3374 highlights the distinction between ground distance and grid distance (Figures 7 and 8). PSM 3374 was analysed and adjusted for Earth's curvature and atmospheric conditions; the grid distance was calculated to be approximately 410.98 meters.

Fig. 7 The comparison of ground distance to grid distance

Fig. 8 Plain distance observation

The discrepancy between these distances arises from several factors like Earth's curvature**,** projection distortions and measurement methodology.

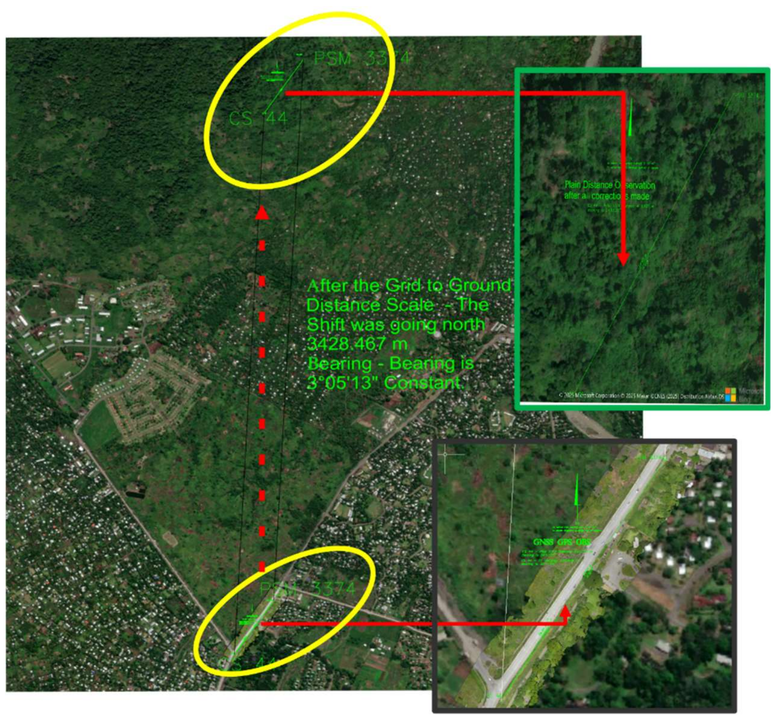

Fig. 9 Position shift observed

Figure 9 demonstrates the positional shift observed after applying the scale factor to the coordinates. This scale factor was determined based on the ground distance measurements obtained from the Total Station. By scaling the actual ground distance against the GPS observations, a new set of adjusted coordinates was plotted. The CAD plot revealed a different position, which aligns with the actual coordinates. The coordinate shift maintained a consistent distance of approximately 3428.467 meters, with a bearing of 3 degrees, five minutes, and 13 seconds moving up for both stations, CS 44 and PSM 3374. This highlights the importance of applying the correct scale factor when conducting fieldwork, as even small discrepancies between Total Station (EDM) and GPS observations can result in significant shifts that may impact project accuracy. The final result was achieved after all necessary corrections and adjustments were made.

In summary, while the ground distance provides a direct measurement between points on the Earth's surface, the grid distance is a projection-based representation that necessitates corrections to align accurately with the actual ground measurements. The analysis of CS 44 and PSM 3374 underscores the importance of these corrections to ensure precision in geospatial measurements.

3.1 Use of grid Convergence, True bearing to grid bearing, and FSM Bearing to Grid Bearing

In geospatial analysis, especially in regions like Papua New Guinea (PNG), understanding the concepts of grid convergence, true bearing to grid bearing, and FSM bearing to grid bearing is crucial for accurate mapping and surveying.

The Fourmill Standard Meridian (FSM) is a specific meridian used in geospatial analysis and surveying within Papua New Guinea (PNG). It serves as a reference line for mapping and coordinate systems in the region. The FSM is crucial for ensuring accurate positioning and alignment of survey data, as it helps to standardize measurements and reduce discrepancies caused by the Earth's curvature and projection distortions.

Grid convergence refers to the angle between true north and grid north on a map. This angle varies across different regions due to the Earth's curvature and the projection used to create the map. In PNG, where topography can be complex, accounting for grid convergence ensures that maps accurately represent the true positions of features on the ground.

True bearing is the direction from one point to another measured in degrees from true north. Grid bearing, on the other hand, is the direction measured from grid north on a map. To convert true bearing to grid bearing, one must account for the grid convergence angle. For example, if the grid convergence is 3 degrees east, you would subtract 3 degrees from the true bearing to get the grid bearing.

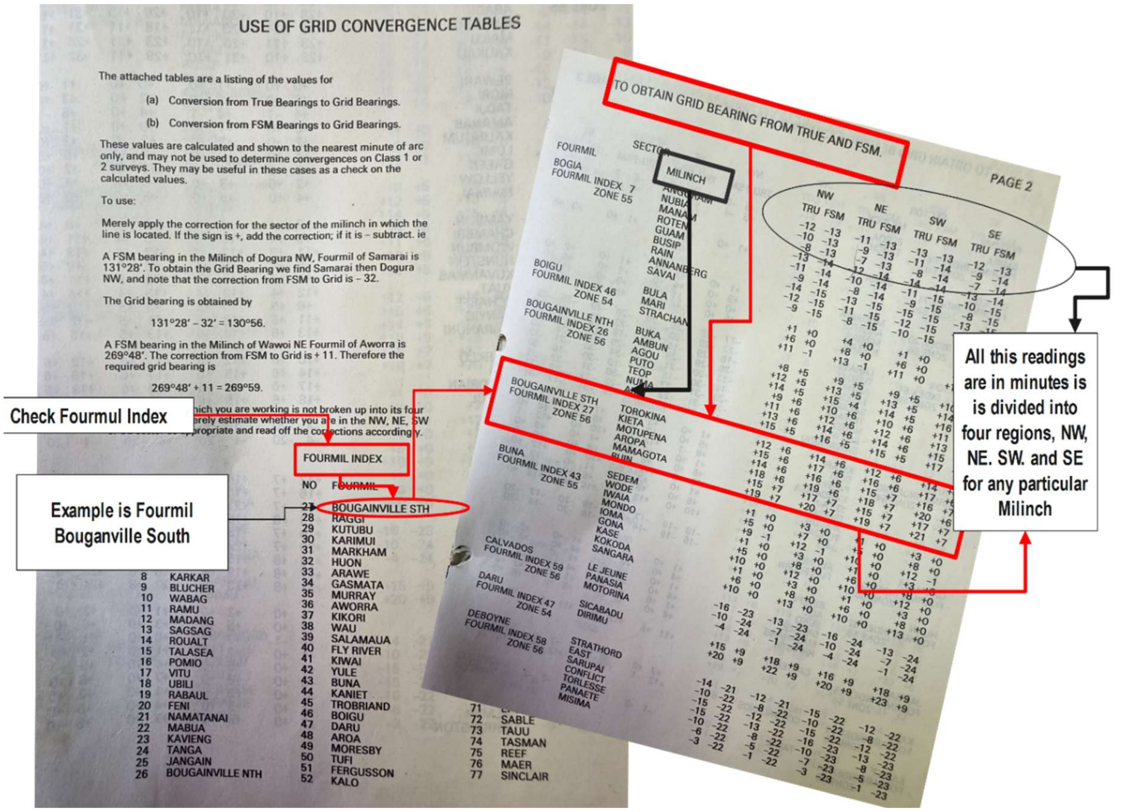

Fig. 10 FSM and true bearing conversion to grid bearing

The Fourmill Standard Meridian (FSM), established under the survey direction of 1990, has become outdated. Figure 10 illustrates the technical process of converting from FSM and true bearing to grid bearing see figure 10, which is indeed a lengthy procedure. According to the survey direction of 1990, the Fourmil Index includes the names of places categorized by their specific zones (54, 55, and 56). Within each Fourmil (Place) zone, specific True and FSM readings are assigned in minutes, though these values are approximate.

The Milinch sections, which specify the place names, come with designated True and FSM readings. Despite the advent of more advanced technologies and methodologies, the FSM has not been updated since 1990, leading to its continued use on many cadastral plans in Papua New Guinea. This outdated system poses significant challenges in accurately converting and aligning survey data.

The conversion from FSM to grid bearing involves multiple steps, including calculating grid convergence, applying scale factors, and adjusting for projection distortions. The lack of updates to the FSM means that discrepancies between traditional survey methods and modern GPS measurements can result in substantial positional shifts, potentially impacting project accuracy. Given the importance of precise geospatial data for various applications, it is crucial to apply the appropriate scale factors and correction methods. Properly updated and maintained surveying standards ensure that cadastral plans and other geospatial data remain accurate and reliable for land development, resource management, and environmental studies in Papua New Guinea. The need for modernization and regular updates to the FSM and related survey data is evident to prevent significant shifts that could affect the accuracy of projects and work conducted on the ground.

3.2 Calculations of FSM, Grid North, True Bearing, Grid Convergence, and Magnetic North for CS 44 and PSM 3374.

To ensure comprehensive geospatial measurements, the calculations for FSM, Grid North, True Bearing, Grid Convergence, and Magnetic North were conducted for the points CS 44 and PSM 3374. The FSM, established under the survey direction of 1990, remains a key reference for many cadastral plans in Papua New Guinea, despite its outdated status. Grid North was determined based on the UTM zone and central meridian, providing precise alignment within the grid system.

3.3 Fourmil Standard Meridian North as a Baseline Reference North for CS 44 and PSM 3374 to Determine Old Marks

This heading indicates the importance of using the Fourmil Standard Meridian North as a baseline reference for accurately determining and locating old survey marks, such as control points (OCPs), for CS 44 and PSM 3374 within the survey plan. This approach ensures consistency with historical data and accurate alignment of coordinates, maintaining the integrity of cadastral boundaries and geospatial data.

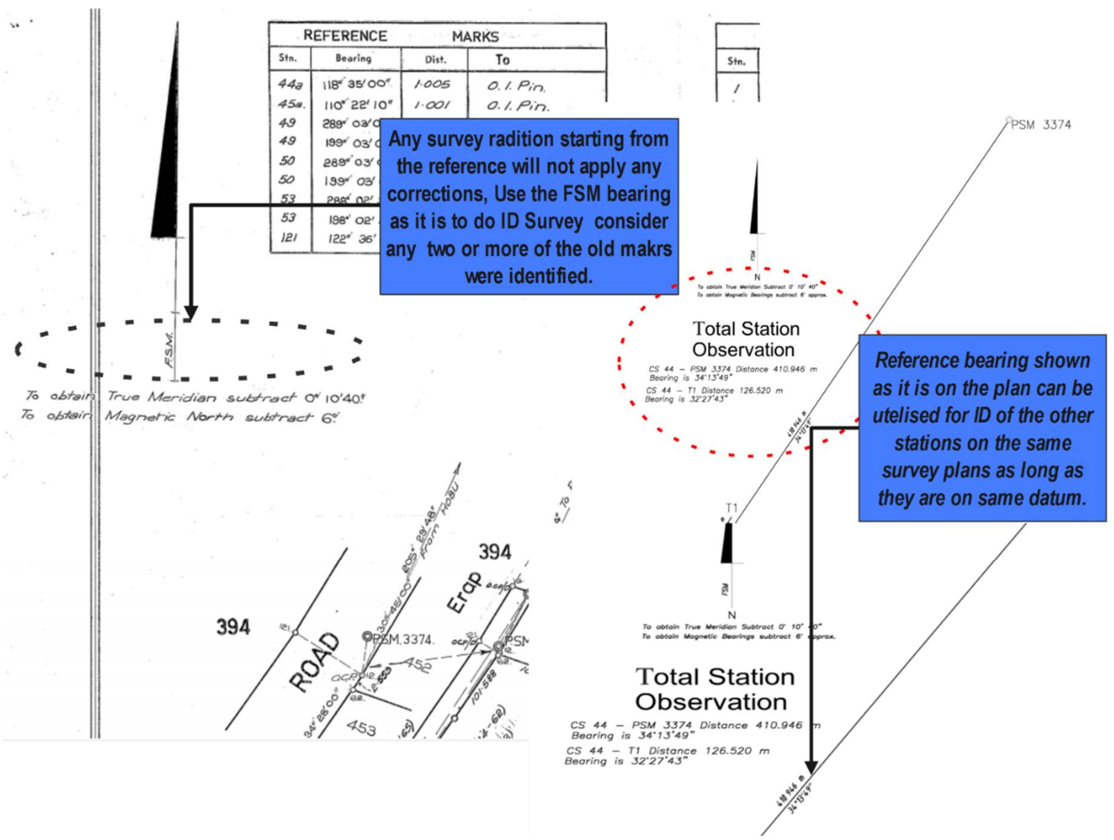

Fig. 11 Meridian conversion

Figure 11 demonstrates the significance of applying the meridian conversion for any survey execution. Since the survey plan (Cat file 31/529) indicates the north direction based on the Fourmil Standard Meridian (FSM), all surveys, particularly the identification of old cement pegs, must use the FSM bearing to accurately identify any survey marks. Establishing GPS static observations on any of the two marks on the survey plan to use as references will also require conversion to the FSM grid. This conversion is shown above on the North arrow as (to obtain true meridian subtract 0º10’40”) or vice versa. Properly applying these conversions ensures the accuracy and reliability of the survey, maintaining the integrity of cadastral boundaries and geospatial data.

3.4 Poor Magnetic North update on record

Due to the poor updates of the survey direction, the study identified that the magnetic bearing declination was outdated for any particular point on the Earth's surface. Magnetic bearing changes over time, and because of the lack of continuous updates to survey plans, outdated records are still in use. Below is the proof of calculation carried out comparing the magnetic bearing of the existing Mark CS 44 with the magnetic bearing calculated using a magnetic bearing calculator. This confirms that all our survey plans need proper updates over time.

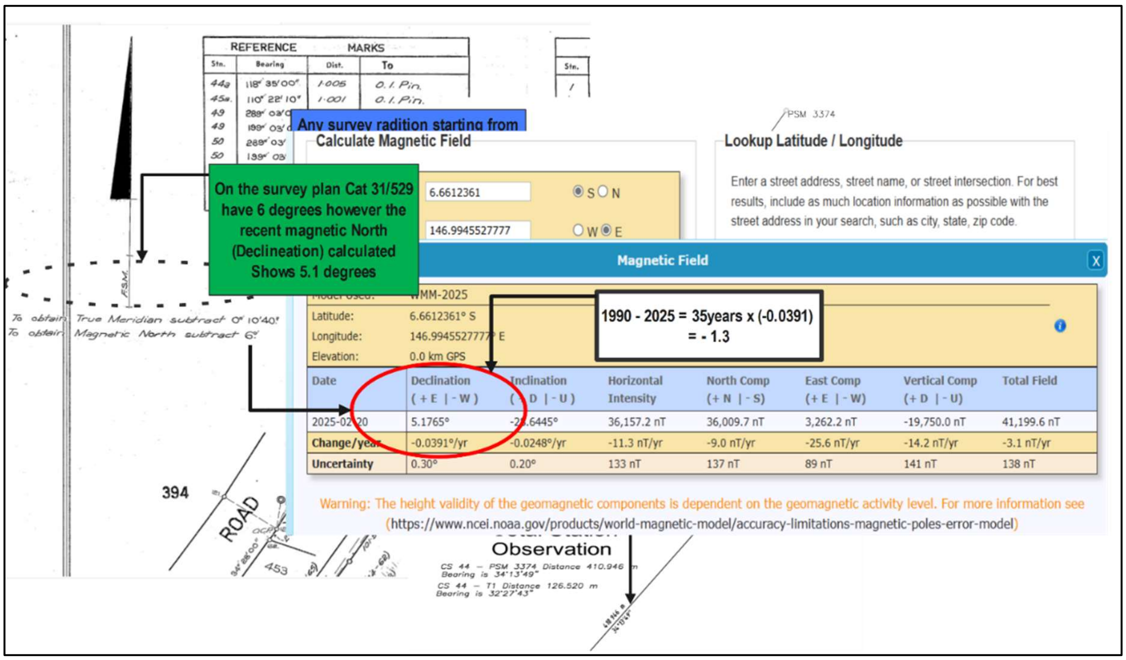

Fig. 12 Declination of Magnetic north bearing

The calculations showed significant differences between the historical magnetic declination recorded for CS 44 and the current magnetic declination obtained from the magnetic bearing calculator. Such discrepancies highlight the necessity for regular updates to ensure accurate and reliable geospatial data in surveying projects. By keeping survey plans updated with the latest magnetic declination values, we can maintain the integrity and precision of cadastral boundaries and other geospatial information.

Changes in magnetic north occur at a rate of -0.0391º per year (figure 12). Unfortunately, this has often been overlooked, with updates not made even for return periods of 5 or 10 years. Imagine not updating for 35 years; this results in a significant gap. Cat.31/529 was used for this study, and when compared to other survey plans, it is evident that proper updates are lacking. This is a serious matter affecting all our survey plans given current technologies and methodologies. The survey direction of 1990 needs to be updated to reflect modern surveying practices, ensuring that all data is accurate and reliable. Regular updates are essential to maintain the integrity of our geospatial information and to prevent discrepancies that could impact land management and development projects.

3.5 Detailed Steps for Calculating Grid Convergence, True Bearing, and FSM Bearing for CS 44 and PSM 3374

- **Calculate Grid Convergence**
  - Determine **the Central Meridian** of the UTM zone. For UTM Zone 55S, the central meridian is at 141° E.
- **Calculate the Longitude Offset**
  - Longitude of Point A (CS 44): 146.9946° E
  - Longitude of Central Meridian: 141° E
  - Longitude Offset = 146.9946° - 141° = 5.9946°
- **Calculate Grid Convergence**

Latitude of Point A (CS 44): 6.6612° S

Formula: Grid Convergence = Tan(Longitude Offset)×Sin(Latitude)

Grid Convergence=Tan(5.9946°)×Sin(6.6612°) ≈ 0.105×0.116≈0.0122 = *approx. 0.0122 radians – In degrees 0.70°*

- **Calculate True Bearing**
  - Determine Coordinates
  - Point A (CS 44): Northing = 9267919.492 meters, Easting = 499837.108 meters
- **Calculate Differences**:
  - ΔE\Delta E (Easting Difference) = 499606.969 - 499837.108 = -230.139 meters
  - ΔN\Delta N (Northing Difference) = 9267579.033 - 9267919.492 = -340.459 meters
- **Calculate True Bearing**:
  - True Bearing=Atan2(−230.139, −340.459) ≈ *214°03'26" (34°03'26")*
- **Calculate FSM Bearing**
  - Determine FSM Grid Direction**:** FSM Grid adjustment shown on North arrow as (to obtain true meridian subtract 0º10'40").

By following these steps, you can accurately calculate the grid convergence, true bearing, and FSM bearing for CS 44 and PSM 3374. This ensures precise geospatial measurements for surveying and mapping projects, maintaining the integrity of cadastral boundaries and geospatial data.

4. Conclusion

This study has identified several key findings regarding the use of the Fourmil Standard Meridian (FSM) in cadastral surveys, particularly in Papua New Guinea (PNG). The FSM, established in 1990, has not been consistently updated, resulting in discrepancies in survey plans. By comparing FSM, grid convergence, true bearing, and magnetic north bearing for CS 44 and PSM 3374, the study highlights the importance of regular updates to maintain accuracy.

Significant findings include the necessity of converting and aligning coordinates accurately using FSM bearings and the effects of changes in magnetic north, which occur at a rate of -0.0391º per year. The lack of continuous updates has led to outdated records, impacting the reliability of geospatial data.

The study underscores the importance of modernizing the survey direction and regularly updating survey plans to reflect current technologies and methodologies. This will ensure precise geospatial measurements, support effective land management, and maintain the integrity of cadastral boundaries in PNG. Properly addressing these issues is crucial for the continued accuracy and reliability of surveying projects in the region.

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