The Application of UAV & Remote Sensing for Rural Development in Western Province of PNG

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ABSTRACT

The field of town planning is one of the many areas in city life where "Unmanned Aerial Vehicles" (UAVs) and drones could find use. When compared to traditional surveying options, drones may offer planners a more accurate, precise, flexible, and economical means of obtaining information. To maximize the public benefit from the use of 'drone technology' in town planning, town planners and surveyors require flexible, practical drone regulations that address the numerous concerns surrounding the use of UAVs in urban areas.

This research presents a case study on the application of 'Unmanned Aerial Vehicles' and 'Remote Sensing technologies' for rural development in Papua New Guinea, specifically focusing on the Nomad District Planning in the Western Province. The study aims to examine the potential of UAVs and remote sensing in addressing the challenges faced by rural communities in terms of land-use planning, infrastructure development, and natural resource management. The case study begins by providing an overview of the current state of rural development in Papua New Guinea and highlighting the specific issues faced by the Nomad District.

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1.1 INTRODUCTION

In recent years, there has been a growing recognition of the potential of 'Unmanned Aerial Vehicles' and 'remote sensing technologies' in addressing the challenges faced by rural communities in terms of land-use planning, infrastructure development, and natural resource management. These technologies offer opportunities for high-resolution data acquisition, flexibility, and relatively low cost, making them invaluable tools for rural development initiatives (Kieu & Law, 2021). They have the potential to overcome the limitations of traditional data collection methods in remote and difficult-to-access regions. By utilizing UAVs and remote sensing technologies, the Nomad District in Western Province, Papua New Guinea can overcome these challenges and enable sustainable rural development.

Papua New Guinea is a country with significant socio-economic challenges, particularly in rural areas. Rural communities in the Nomad District face limited access to basic services such as healthcare, education, and infrastructure. This hinders their overall development and contributes to high levels of poverty and inequality. PNG faces socio-economic challenges despite its natural resources. As of 2001, the per capita income was significantly lower than the world average and that of neighboring Southeast Asian countries(Auty, 1991; Kamat, A. et. al, 2022). These economic disparities underscore the need for innovative approaches to rural development.

UAVs and remote sensing technologies have great potential to contribute to rural development in the Nomad District of Western Province, Papua New Guinea (Li et al., 2010). These technologies can provide valuable insights into land use, infrastructure, and natural resources, allowing for informed decision-making and targeted interventions.

2.0 RESEARCH MATERIAL METHODOLOGY

2.1 Study Area

The study area for this research is the Nomad District of Western Province in Papua New Guinea (Fig 1). This district is a predominantly rural area with limited access to resources and services, making it an ideal case study for exploring the application of UAVs and remote sensing technologies in rural development. The Nomad District is characterized by diverse geographical features, including forests, rivers, and agricultural lands. It is also home to several rural communities that heavily rely on agriculture and natural resources for their livelihoods.

Nomad District, located in the Western Province of Papua New Guinea, experiences a tropical climate with high temperatures and humidity throughout the year. The region has a distinct wet season from December to June and a dry season from July to November. During the wet season, the area receives heavy rainfall, while the dry season is characterized by lower precipitation and higher temperatures.

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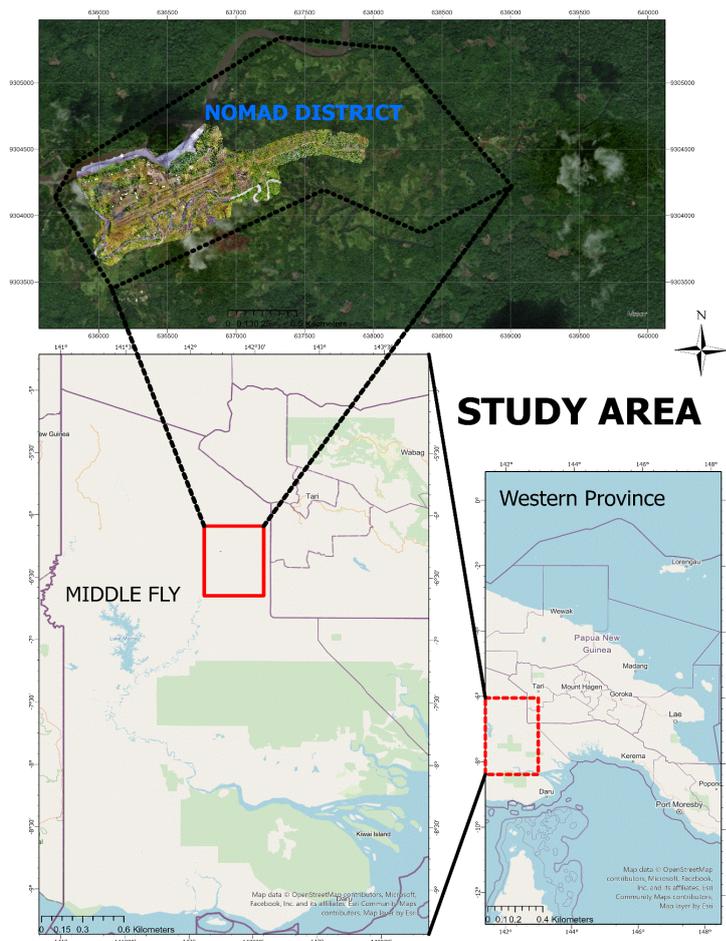Cape Town, South Africa, 24–29 May 2026

Figure 1 Showing the Nomad District Map or the Study Area in Western Province, PNG

2.2 Methodological Flow Chart

The workflow diagram (Fig 2) for this study outlines the systematic process followed, starting with data collection using UAVs to capture high-resolution aerial imagery of the Nomad District. Next, the data processing phase involves using software like Agisoft to create Digital Elevation Models (DEMs) and Digital Surface Models (DSMs), incorporating Ground Control Points (GCPs) for accuracy. Finally, the integration and reporting phase consolidates the analyzed data into a comprehensive master plan for rural development, which includes visualization, stakeholder engagement, and adherence to regulatory requirements (Stephen John et al, 2022; Veal R. et al, 2019; Huany, M. et al,2022). This structured approach ensures thorough and accurate planning, leveraging modern technology to enhance traditional survey methods.

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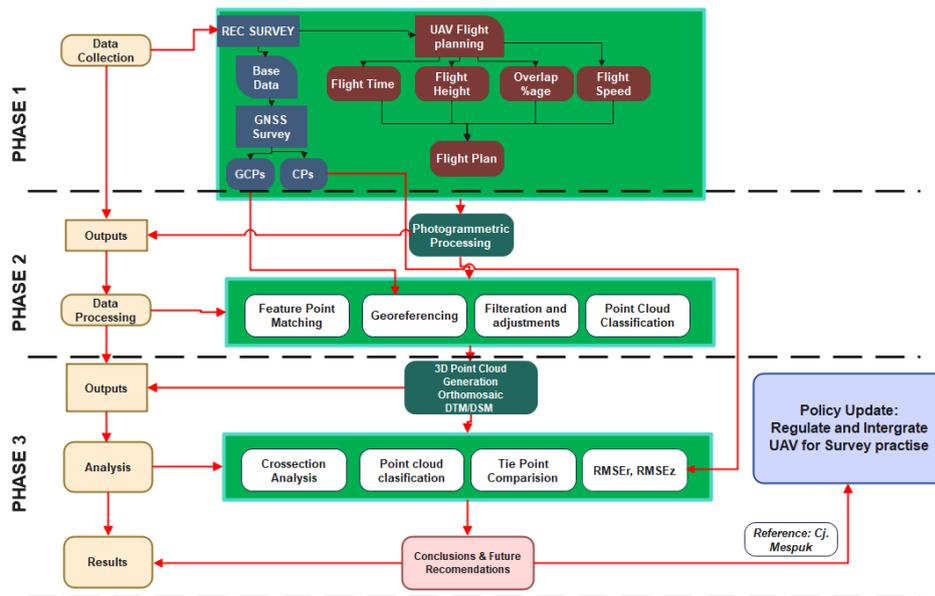Cape Town, South Africa, 24–29 May 2026

Figure 2 Showing the workflow method executed for this research

3.0 RESULTS AND DISCUSSIONS

3.1 Survey Control Points

Survey control points (Table 1) are the GCPs or ground control points and CPs check points established using the Topcon Hyper SR GPS receivers. Provided below are the post processed control points using Topcon Magnet Office Tools software.

Table 1 Showing the post processed survey control points from Topcon magnet office tools.

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 Separation (m)
GCP5	9303959.874	636401.299	90.837	0.001	0.001	0.002	0.001	76.186
GCP6	9303510.604	636224.524	93.305	0.001	0.001	0.003	0.002	76.172
GCP7	9304268.751	636004.85	88.153	0.003	0.004	0.009	0.005	76.182
GCP8	9304378.233	636293.257	90.612	0.002	0.003	0.005	0.003	76.192
GCP9	9304378.184	636657.809	91.09	0.001	0.002	0.002	0.002	76.201
GCP10	9304412.224	636961.453	94.086	0.001	0.001	0.002	0.001	76.21
GCP11	9304419.926	637248.703	98.679	0.001	0.002	0.004	0.002	76.217

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AA430	9304228.14	636437.88	92.13	0	0	0	0	76.192
GCP12	9304540.525	637642.733	101.265	0.002	0.003	0.005	0.004	76.231
GCP13	9304505.751	637918.559	107.168	0.001	0.001	0.003	0.002	76.237
GCP14	9304454.253	638085.288	119.055					76.24
GCP15	9304529.761	638424.938	95.244					76.251
GCP16	9304392.938	638062.035	55.616					76.238
GCP17	9304281.128	637943.315	59.202					76.232
GCP1	9304185.047	636219.916	89.57	0.085	0.024	0.088	0.089	76.186
GCP2	9304032.926	636093.984	97.854					76.179
GCP3	9303885.59	636084.604	90.302	0.001	0.001	0.002	0.001	76.176
GCP4	9304114.227	636385.282	91.507	0.001	0.001	0.002	0.002	76.189

The above table 1 illustrates the survey control points established on the ground using the Topcon Hyper Sr GPS receivers. The base station was at PSM AA430. We fixed all vertical and horizontal positions using the base mark (PSM AA430). The ground control points indicated in red were not post processed, as satellite observations were not accessible through the survey data collections. Nevertheless, we employed the satellite-observed survey control to geo-correct the remaining points that were captured, while excluding the points that were highlighted in red. The PNG 94 survey datum is employed to localize all vertical and horizontal survey controls. The figure 3 below shows the post processed GPS point occupations and observation results from the Topcon Magnet Office Tools software.
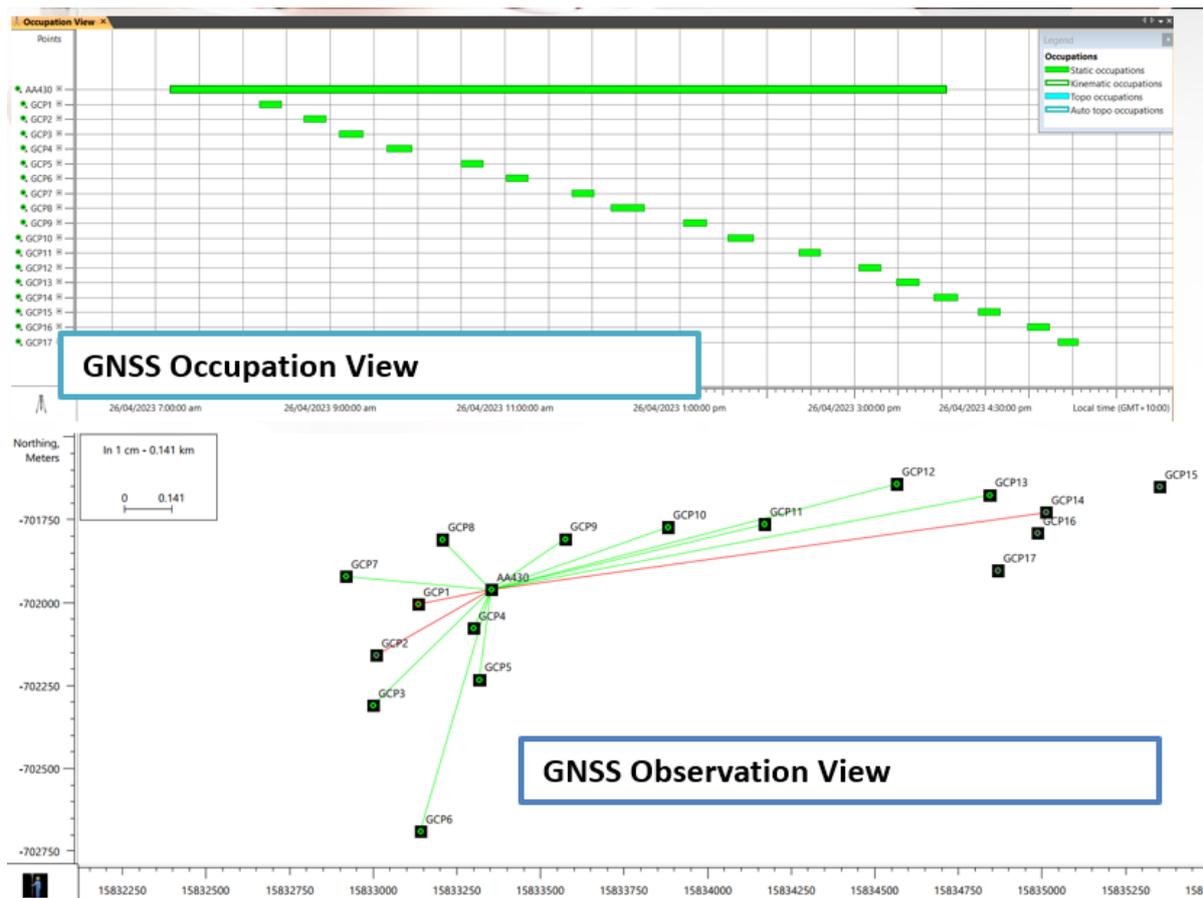
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Figure 3 Showing the post process report of the GPS point observation and station occupation from the Topcon magnet office tools software

The MAGNET Tools software suite was developed by Topcon to facilitate the processing, adjustment, and visualization of field-survey data obtained from GNSS equipment and total stations. Red and Green Lines: These lines typically denote distinct forms of data or measurements. For instance, red lines may suggest errors or areas that require transformation, while green lines may represent data points that have been correctly processed (Table 2). GNSS Data Results: We employ GNSS (Global Navigation Satellite System) data to identify precise locations on Earth. MAGNET Tools enables you to post process this data (Fig 3) in order to enhance accuracy and rectify any errors. The table below displays the root squared mean error from the survey control result, which falls well within the survey's bounds.

Table 2 Showing the table result of the corrections made for the individual points including the precision results.

Point From	Point To	Start Time	Duration	Horizontal Precision (m)	Vertical Precision (m)	dN (m)	dE (m)	dHt (m)	Method	Solution Type
AA430	GCP5	26/04/2023 10:29	0:15:41	0.001	0.002	-268.27	-36.58	-1.299	PP	Fixed

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AA43 0	GCP6	26/04/202 3 11:00	0:15:38	0.002	0.003	-717.54	-213.4	1.155	PP	Fixed
AA43 0	GCP7	26/04/202 3 11:45	0:15:35	0.005	0.009	40.611	-433	-3.988	PP	Fixed
AA43 0	GCP8	26/04/202 3 12:13	0:23:12	0.003	0.005	150.09 3	-144.6	-1.519	PP	Fixed
AA43 0	GCP9	26/04/202 3 13:02	0:16:34	0.002	0.002	150.04 4	219.9 3	-1.031	PP	Fixed
AA43 0	GCP10	26/04/202 3 13:33	0:18:00	0.001	0.002	184.08 4	523.5 7	1.973	PP	Fixed
AA43 0	GCP11	26/04/202 3 14:21	0:15:15	0.002	0.004	191.78 6	810.8 2	6.574	PP	Fixed
AA43 0	GCP12	26/04/202 3 15:03	0:15:23	0.004	0.005	312.38 5	1204. 9	9.173	PP	Fixed
AA43 0	GCP13	26/04/202 3 15:28	0:15:52	0.002	0.003	277.61 1	1480. 7	15.08 2	PP	Fixed
AA43 0	GCP14	26/04/202 3 15:54	0:08:27						PP	Failed, No Satellites
AA43 0	GCP1	26/04/202 3 8:11	0:15:32	0.089	0.088	-43.093	-218	-2.567	PP	Fixed
AA43 0	GCP2	26/04/202 3 8:42	0:15:29						PP	Failed, No Satellites
AA43 0	GCP3	26/04/202 3 9:06	0:16:50	0.001	0.002	-342.55	-353.3	-1.844	PP	Fixed
AA43 0	GCP4	26/04/202 3 9:39	0:17:21	0.002	0.002	-113.91	-52.6	-0.627	PP	Fixed

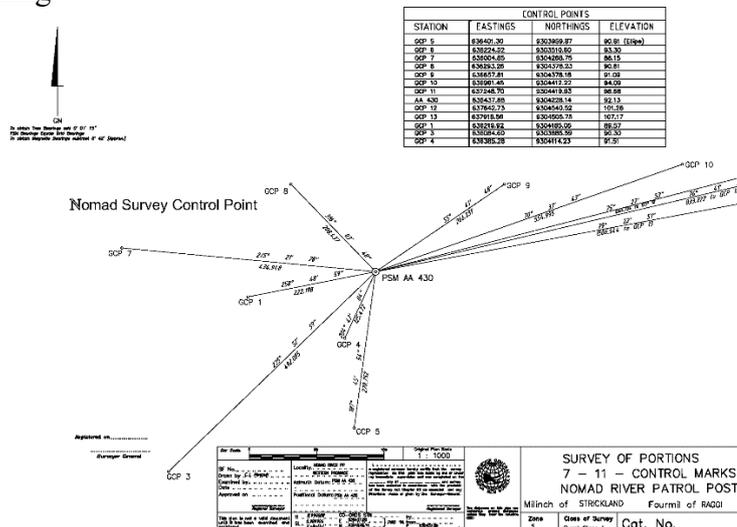Figure 4 below shows the results of the control survey that was carried out using static point positioning.

Figure 4 Showing the result of the survey control points plotted on civil cad (AUTO-CAD) – Check

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3.3 UAV/DRTK Survey

UAV surveys involve using drones equipped with sensors to capture aerial data. These sensors can include RGB cameras, multispectral cameras, or LIDAR payloads. The data collected is used to create geo-referenced maps, elevation models, 3D models, and more. UAV surveys are known for their efficiency, accuracy, and ability to access difficult terrains.

The D-RTK 2 Mobile Station by DJI is a high-precision GNSS (Global Navigation Satellite System) receiver. It supports multiple satellite systems (GPS, BEIDOU, GLONASS, and Galileo) and provides survey-grade accuracy for various DJI enterprise drones. Land surveyors and civil engineers use the D-RTK 2 for precise positioning and data collection, making it a valuable tool.

We selected two sites for the UAV deployment: one at Nomad Station, and another at a proposed administrative site, where we used ground control points for UAV purposes and adjustments. This research will focus on the second site, especially for UAV procedures and discussions.

3.3.1 UAV Flight – Site A

The UAV survey at site A involves capturing an ortho-photo image of all nomad stations, including the established ground control points. Procedure for adjustments and georeferenced images will be elaborated on the UAV flight captured on the second site (Site B). We positioned all ground control points using PSM AA 430 as the base reference marks.

Figure 5 below shows the georeferenced image captured for Nomad Station, which is referred to as site A. We made all necessary adjustments, but it wasn't necessary to focus on the UAV adjustment in detail, especially for site A.
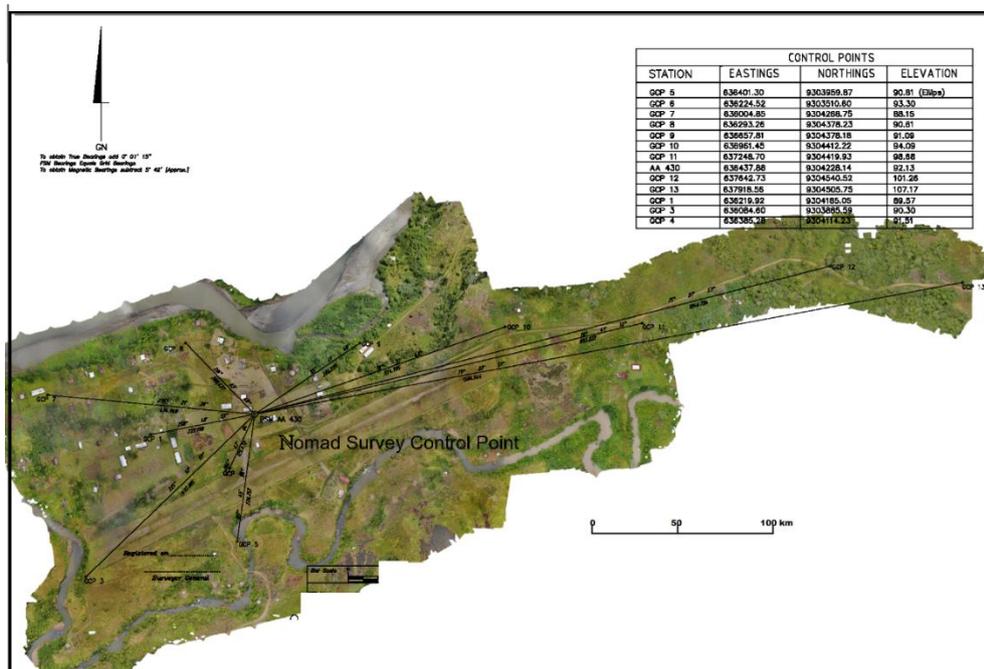

Fig. 5 UAV data collected overlaid on the Survey control points for site A: Check

We identified potential construction sites and selected specific locations for rural development using the created elevation model. We selected a couple of proposed sites for development: the

residential site, the hospital site, and the police station headquarters. Using the UAV data for Site A, Figure 6 below shows the proposed subdivision of the residential site and airport extension.

Fig. 6 Proposed residential site that was allocated using the UAV image.

We used the analyzed terrain data to establish subdivision zones for the sites. By leveraging this data, we design more efficient and accurate site layouts, taking into account the natural features and topography. Figure 7 shows the proposed site for the hospital and police station.

Fig. 7 Proposed Police Station and the hospital site for Nomad District

Following are the steps taken into consideration with the planning act to create subdivision zones using terrain analysis

❖ Data Collection: Gather high-resolution terrain data using UAV surveys, GNSS, or other methods.

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- ❖ DEM Creation: Generate a Digital Elevation Model (DEM) to visualize the terrain in detail.
- ❖ Slope Analysis: Use the DEM to analyzed slopes, which can influence where roads, buildings, and utilities are best placed.
- ❖ Watershed Analysis: Identify drainage patterns to ensure proper water management and reduce the risk of flooding.
- ❖ Subdivision Layout: Design the subdivision layout by incorporating the terrain data, ensuring optimal land use and minimal environmental impact.
- ❖ Zoning: Assign different zones based on the terrain features, such as residential, commercial, and recreational areas.

We developed the subdivision master plan for Nomad District using UAV survey data, which integrates high-resolution aerial imagery and terrain analysis to create an accurate and efficient layout. The UAVs captured detailed topographical data, enabling the creation of a Digital Elevation Model (DEM). This model highlights the area's slopes, elevation changes, and natural features, informing the placement of infrastructure such as roads, utilities, and drainage systems. By analysing this data, we designate specific zones for residential, commercial, recreational, and other uses, ensuring optimal land use while minimizing environmental impact. Additionally, the UAV data facilitated a 3D visualization of the subdivision, helping stakeholders and the community understand the proposed development. This visualization included detailed representations of the terrain, infrastructure, and subdivision zones, ensuring that all aspects of the plan were considered and aligned with regulatory requirements. The use of UAV survey data significantly improved the accuracy and efficiency of the planning process, resulting in a well-structured and sustainable master plan for the Nomad District. Following is a master plan generated from the result of the UAV data obtained during the survey (Figure 8).

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Fig. 8 Master plan created from the deployment of the UAV on Site A

3.3.2 UAV Flight – Site B

We executed the UAV plan for site B using the same approach as site A. We employed all necessary steps and procedures, following the methods previously explained. Ground control point 13 (GCP 13) served as the reference station for site B, and we conducted an RTK survey using the Topcon Hyper SR to determine the survey ground control point for the UAV and output are Figure 9 below shows the zoning that was done for site B after the UAV post processed results.
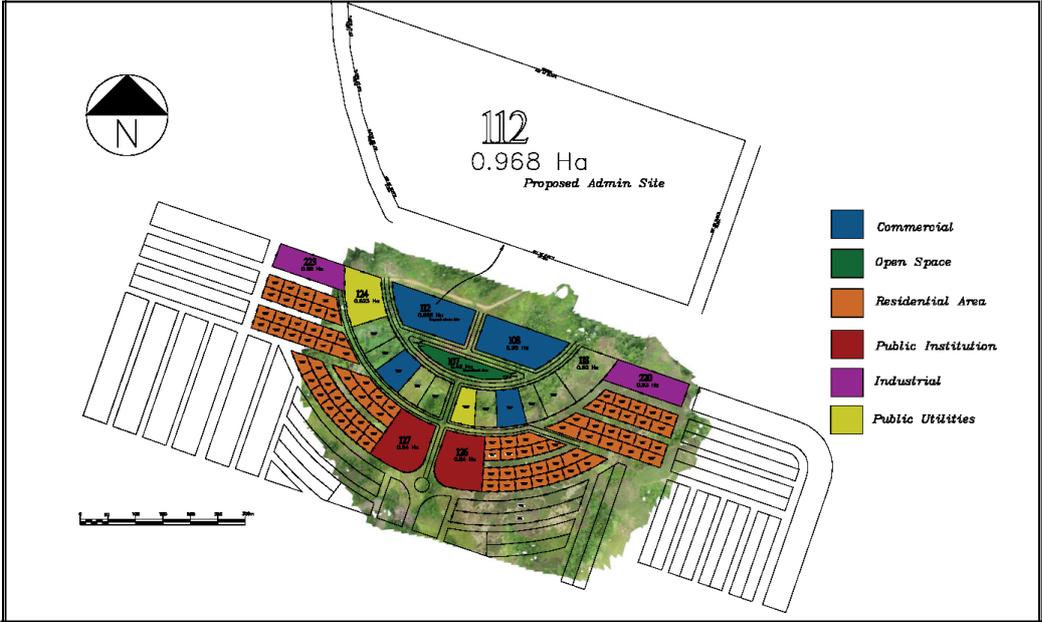
Fig. 9 Post-Processing Zone and subdivision on site B

The proposed subdivision allotment for the admin building site at Nomad Station was meticulously planned using UAV survey data. The data enabled precise identification of suitable locations and detailed mapping of the terrain. This information was crucial for optimizing land use, ensuring the proposed site was ideal for construction, and aligning with overall zoning plans for the area. Further details included infrastructure layouts, environmental assessments, and integration with existing facilities, providing a comprehensive plan to support future development and administrative needs at Nomad Station. The local authority proposed a master plan for the new site at Nomad, aiming to foster sustainable development and meet community needs. Leveraging UAV survey data, the plan detailed strategic zones for residential, commercial, and public infrastructure, including a new administrative building. This comprehensive approach ensured that each zone was optimized for its intended use, taking into account terrain and environmental factors. The master plan also integrated essential infrastructure, such as roads and utilities, ensuring a well-organized and functional layout that supports the growth and development of the Nomad community.

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3.4 Policy and Requirement for UAV survey practise in PNG

In Papua New Guinea, UAV surveying is regulated by the Civil Aviation Safety Authority of Papua New Guinea (CASA PNG). For commercial operations, UAV operators must obtain a drone pilot license, demonstrating their adequate training and qualification. CASA PNG requires the registration of both commercial and hobbyist UAVs. To ensure safety and compliance with aviation standards, the regulations restrict UAVs from flying above 400 meter and from operating at night. Although it's not mandatory, we recommend remote identification for UAVs to improve tracking and safety.
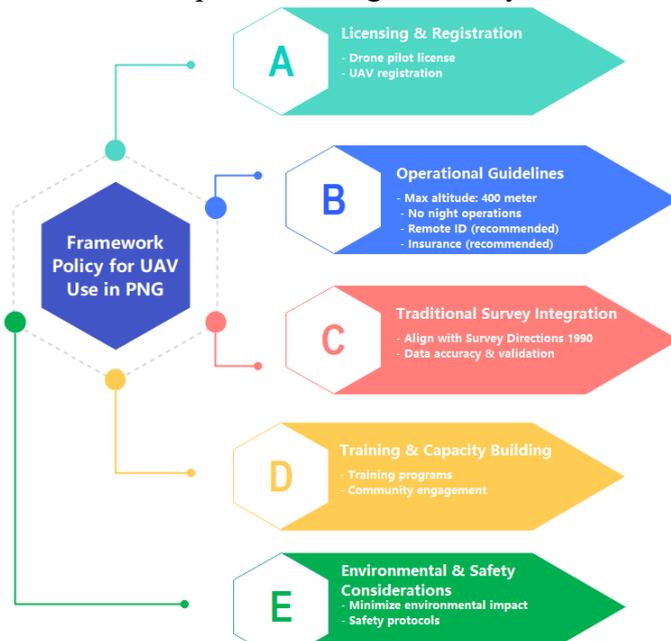

Figure 10 Showing the policy framework developed to control and regulate the usage of drone especially for survey purpose in PNG.

This diagram (Fig 10) captures the essential elements of a robust policy framework for UAV use in surveying, aligned with the 1990 Survey Directions. It emphasizes regulatory compliance, operational guidelines, integration with traditional methods, training, capacity building, and environmental and safety considerations.

The proposed policy framework for UAV (Survey Drone) use in Papua New Guinea (PNG) is designed to integrate modern UAV technology with traditional surveying practices, as guided by the Survey Directions 1990. The framework includes several key components:

1. **Licensing and Registration**: UAV operators must obtain a drone pilot license from CASA PNG for commercial operations, and all UAVs must be registered, ensuring proper documentation and accountability.

2. **Operational Guidelines**: UAVs are restricted to flying below 400 meters and are prohibited from night operations to ensure safety. While remote identification is recommended for enhanced tracking, it is not mandatory. Insurance for UAV operations is also recommended but not compulsory.

3. **Integration with Traditional Methods**: The framework emphasizes aligning UAV surveying with the guidelines established in the Survey Directions 1990, ensuring the

consistency and accuracy of data. It also calls for careful calibration and validation of UAV data against traditional survey data.
4. **Training and Capacity Building**: Implementing comprehensive training programs for UAV operators is essential to ensure proficiency in both UAV technology and traditional surveying methods. Community engagement is encouraged to build local capacity and sustainability.
5. **Environmental and Safety Considerations**: UAV operations should minimize environmental impact, particularly in sensitive areas. Strict safety protocols must be established to protect operators and the public.

This policy framework aims to enhance the efficiency and accuracy of surveying practices in PNG, leveraging UAV technology while ensuring regulatory compliance, safety, and community involvement.

4.0 CONCLUSION AND RECOMMENDATIONS

The application of unmanned aerial vehicles (UAV) and remote sensing technologies presents a transformative opportunity for rural development in Papua New Guinea (PNG), particularly in the Nomad District of Western Province. The integration of these technologies facilitates efficient land use planning, resource management, and socio-economic development by providing accurate and timely data on land cover, population distribution, and environmental changes. For instance, the use of high-resolution remote sensing imagery enables the identification and mapping of rural residential areas, which is crucial for effective planning and management of rural resources. Furthermore, advanced algorithms and machine learning techniques enhance the capabilities of remote sensing in detecting land use changes and classifying scenes, thereby supporting sustainable development initiatives.

We can make several recommendations to maximize the benefits of UAV and remote sensing technologies in the Nomad District:
- First, it is essential to invest in capacity building and training for local stakeholders to ensure they can effectively utilize these technologies for planning and development purposes. This includes developing educational programs that focus on remote sensing applications in agriculture, land management, and environmental monitoring.
- Second, fostering partnerships between government agencies, local communities, and academic institutions can facilitate the sharing of knowledge and resources, leading to more comprehensive and inclusive development strategies.
- Finally, continuous monitoring and evaluation of the implemented strategies using remote sensing data will be crucial for assessing their impact and making necessary adjustments to enhance effectiveness.

Environmental constraints, data quality issues, economic factors, and integration challenges limit the application of UAVs and remote sensing technologies for rural development in PNG. To fully realize the benefits of UAV applications, addressing these limitations requires a multifaceted approach that includes technology investment, training, and the establishment of collaborative frameworks.

In summary, the strategic application of UAV and remote sensing technologies in the Nomad District of PNG holds significant promise for advancing rural development. By leveraging these tools, stakeholders can make informed decisions that promote sustainable growth, improve

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living conditions, and enhance the overall resilience of rural communities in Papua New Guinea.

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