Appendix E Kahuto drone survey

KAHUTO



Tonkin & Taylor Port Villa CBD Vanuatu LiDAR and Imagery Project Report

11th December 2025

Project Summary

Kahuto Pacific has been contracted to provide UAV LiDAR and imagery work at CBD Vanuatu.

Objectives

The objective of the drone survey is to provide an accurate and precise complete site model for the Port Vila CBD area. It was specifically requested for survey points calibrated for post-earthquake tectonic movement. This calibration is essential as the client plans to compare the resulting bare earth model with pre-earthquake models to accurately identify both vertical and potential horizontal ground displacement caused by the seismic event.

Scope of work

The drone survey services is to include, but not be limited to, the following:

- Acquire the necessary permits for drone flight and flightpath.
- Conduct preliminary ground surveys to establish all necessary control points across the subject area. The proposed origins of datums and survey stations must be presented for approval.
- The lateral and height tolerance shall not exceed 50mm.
- Cover the extents within UTM59s Coordinates:

i) 215131, 8035809
ii)215941, 80335666
iii) 216190, 8036870
iv) 215882, 8037451
v)215017, 8037515
vi)214719, 8038918
vii) 214337, 8037953
viii)214900,8036980

LOCATION: The proposed development is located at Port Vila CBD, Vanuatu.

Kahuto will be required to undertake;

- Lidar (Drone) survey
- Imagery (Drone) survey
- Survey Control (GNSS)

Deliverables

The following deliverables should be provided upon completion of the project:

- Controls Survey report in PDF
- LiDAR & Imagery report in PDF
- Drone LiDAR, Imagery GNSS survey to generate complete site model for baseline

topography.

- Bare Earth surface (DEM) as RASTER and DWG
- Contours as DWG
- Ortho Photo as GeoTiff, Ecw, Pdf
- Final plans in PDF and CAD ready format

The delivery of the project is summarized with the below key processes.

- Pre project planning
- Mobilize to site with required equipment
- Transfer control to site with high precision
- Place Control for UAV survey and site control
- Undertake detailed UAV LiDAR imagery acquisition of site
- Process acquired data to project deliverables
- Perform quality control checks on all acquired data and duplicate raw data

Kahuto mobilized to the site and undertook the UAV surveys between the 7th of November to the 11th of November 2025.

During this time, site control was also placed to ensure accurate ties to the previous site datum.

A detailed survey report is provided as an appendix to this report.

Our control used for the site consisted of a number of 17 GCP points and also 3 LiDAR check grids to ensure the LiDAR and imagery work are well aligned to the site coordinates. These control points and coordinates are shown below and can be provided as requested in csv both in UTM59s and TM77 Efate projections.

Acquired UAV LiDAR data was processed, integrated with the survey control and topographic data generated to cover the full area of interest. A high resolution ortho-photo has also been generated.

Flight Planning and Execution

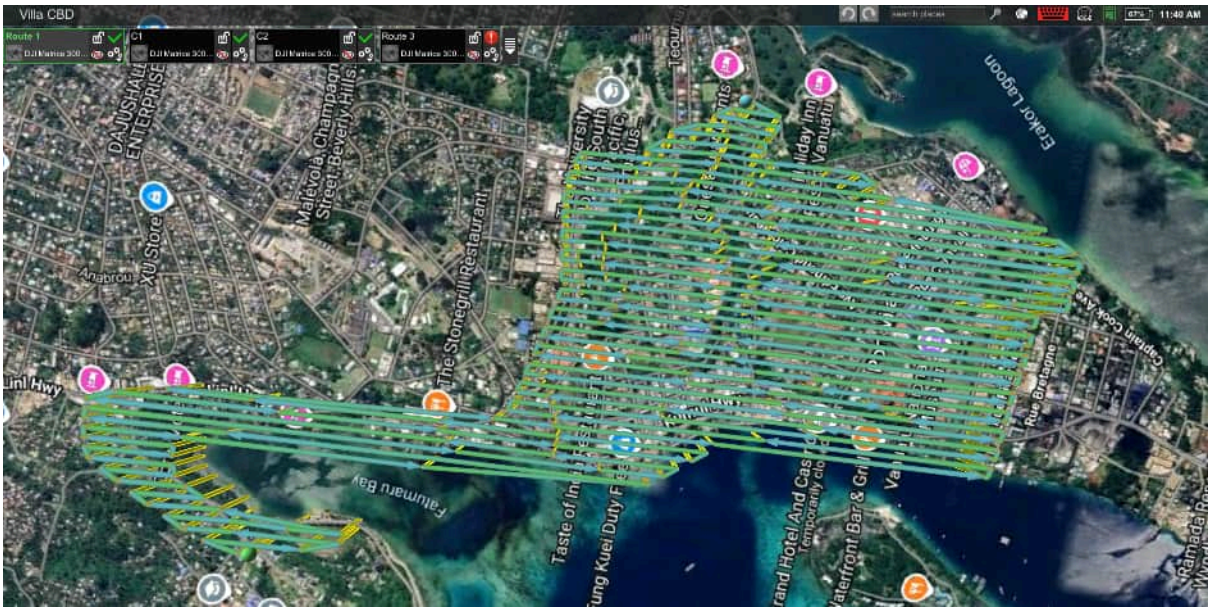
A sufficient 30m buffer was incorporated into the original KML file provided by the client. This ensured comprehensive coverage and high overlap of the area of extent.17 Ground Control Points (GCPs) were sufficient for the site ensuring all region was covered, as is important to provide accurate, on the ground reference coordinates that will tie the drone acquisition data to real-world positions. A total of 3 LiDAR grids are also established at coordinated elevated levels throughout the site, to ensure high Z level accuracy.

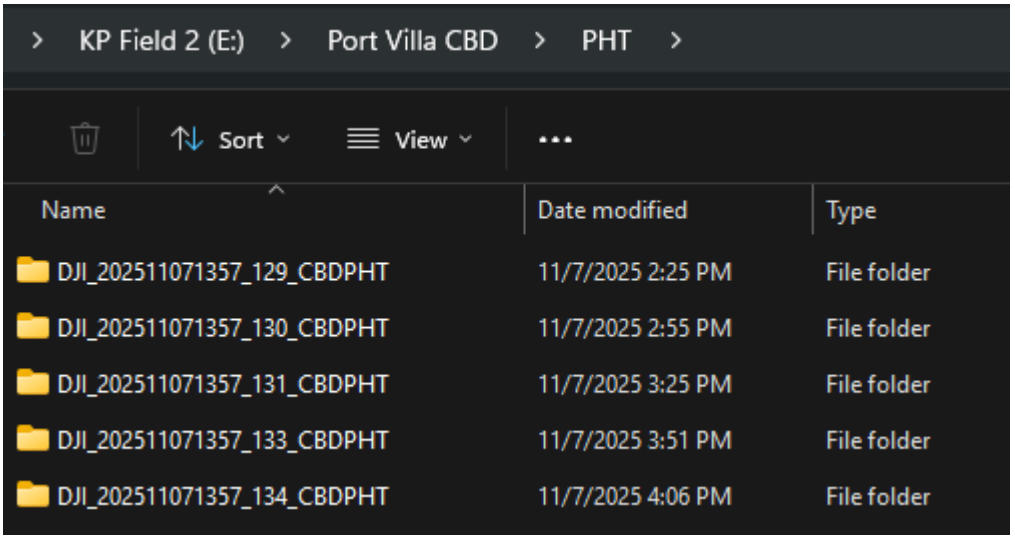
Appropriate Civil aviation NOTAM has been lodged and issued prior to being on site. Following confirmation from the Vanuatu Air Traffic Control team, photogrammetry flights commenced on November 7th, with a total of five flights. LiDAR data acquisition began after completion of photogrammetry, with a total of nine LiDAR flights of the overall site. Followed by 7 concentrated lower altitude flights over the designated slopes/cliffs completed by November 10th. The team promptly ensured all flight data was copied onto secured hard drives and cloud storage. List of remote sensing equipment used and flight planning conducted along with screenshots of the photogrammetry and LiDAR storage folders is provided below.

Photogrammetry Flight plan & Equipment

- IMAGERY: Zenmuse 45MP P1

Positioning: RTK and IMU (site based RTK)



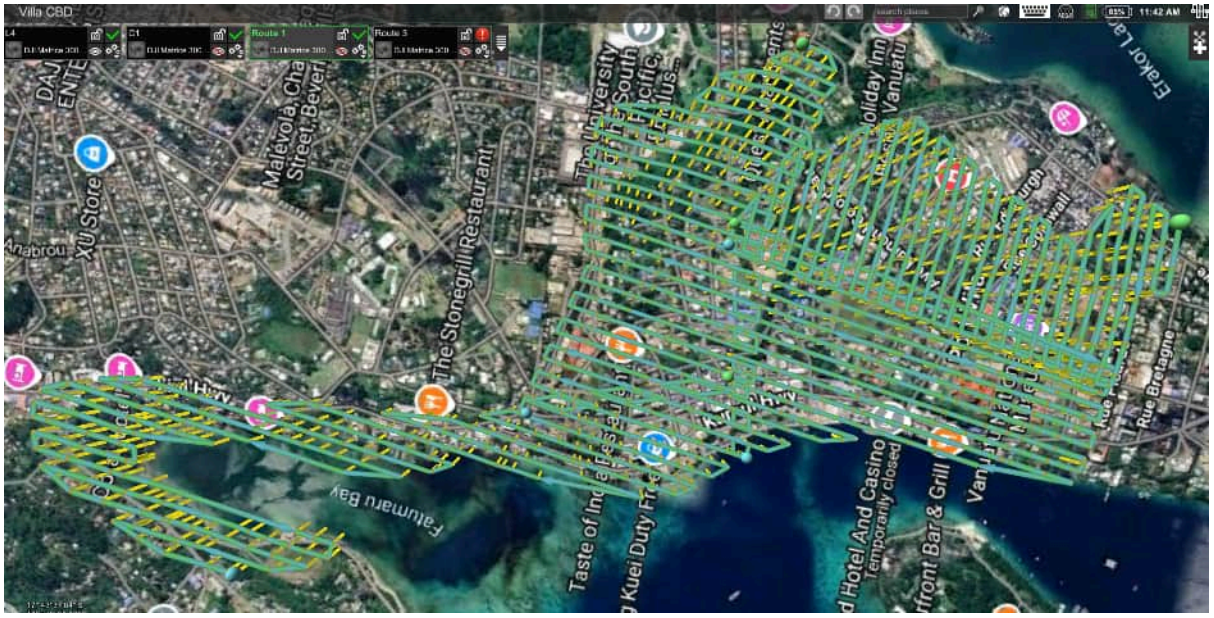


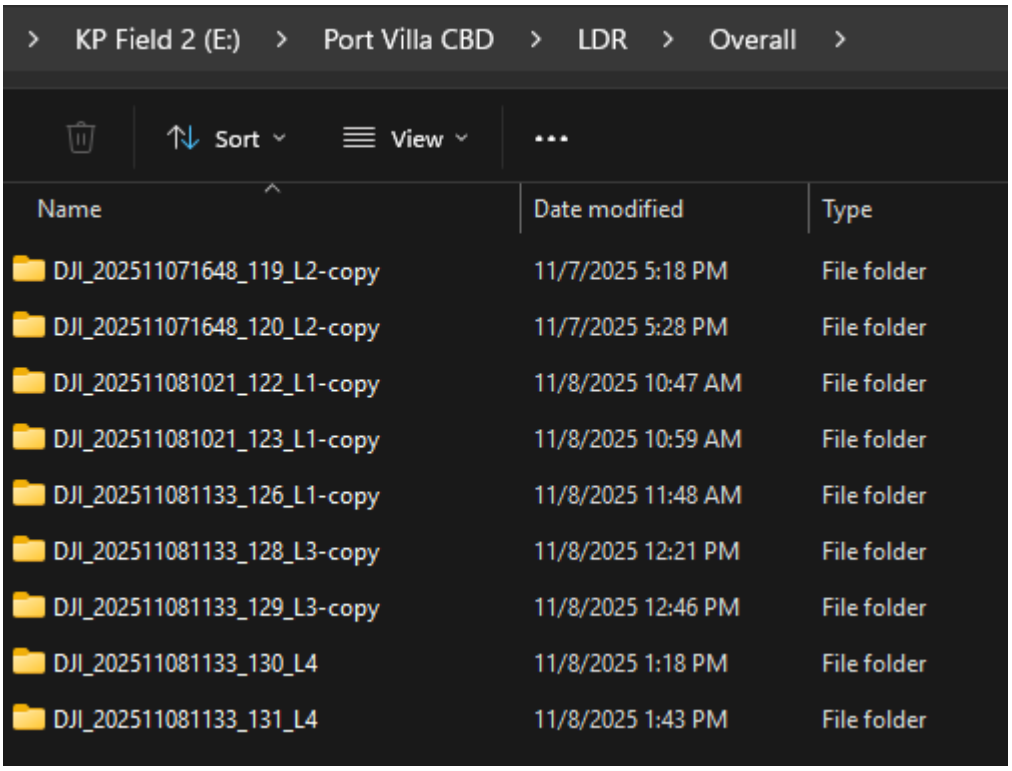
LiDAR flight Plan

- LIDAR: Zenmuse L2 LiDAR Sensor

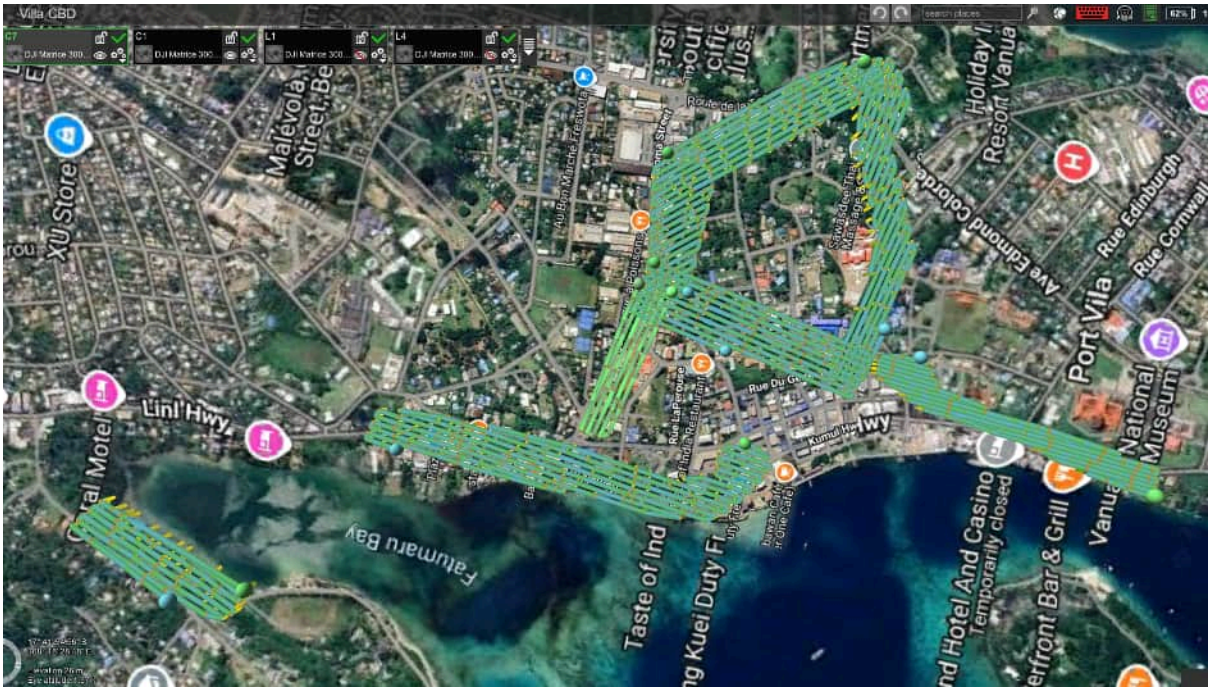
Positioning: RTK and IMU (site based RTK)

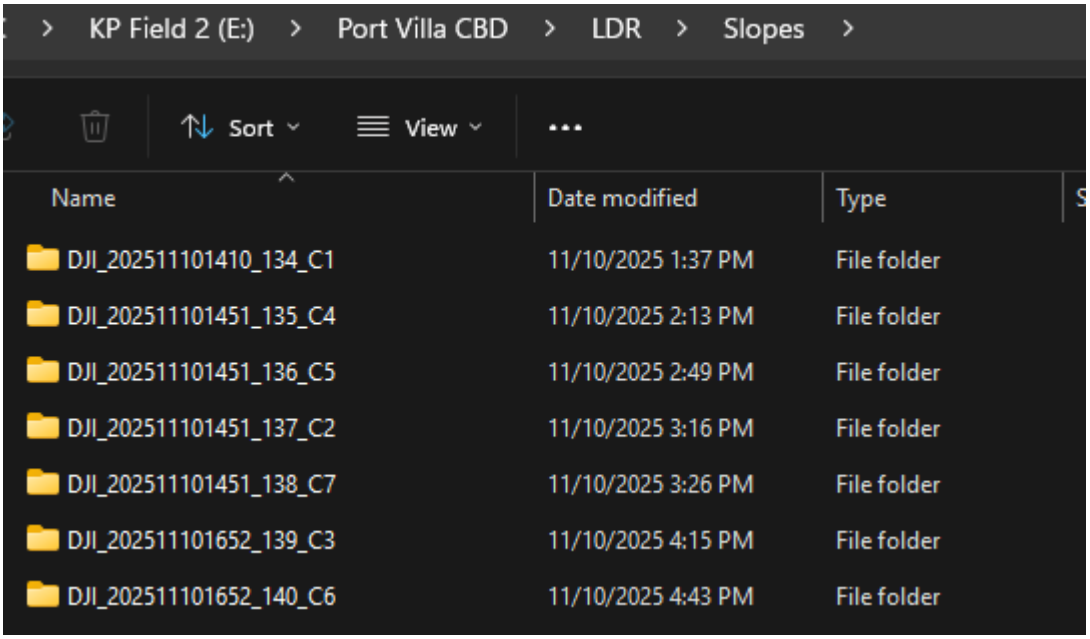
(Flight route for overall site)





(Flight route for slopes)


Villa CBD
Malevola Street
XU Store
Linl Hwy
Fatumaru Bay
Taste of Ind
Port Vila
National Museum
Rue Edinburgh
Rue Cornwall
Ave Edmond Colorado
Holiday Resort Vanua
Hotel And Casino
Temporarily closed
Bar & Grill


KP Field 2 (E:) › Port Villa CBD › LDR › Slopes ›
Sort
View
Name
Date modified
Type
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DJI_202511101451_135_C4 11/10/2025 2:13 PM File folder
DJI_202511101451_136_C5 11/10/2025 2:49 PM File folder
DJI_202511101451_137_C2 11/10/2025 3:16 PM File folder
DJI_202511101451_138_C7 11/10/2025 3:26 PM File folder
DJI_202511101652_139_C3 11/10/2025 4:15 PM File folder
DJI_202511101652_140_C6 11/10/2025 4:43 PM File folder

Survey Projection & Datum

Horizontal Projection: WGS 84 / UTM zone 59 South

Vertical: MSL (Local)

LOCAL COORDINATES - WGS 84 / UTM zone 59 South

GCP	NORTHING	EASTING	MSL (Height)
GCP1	8037986.921	214428.536	1.23
GCP2	8038463.264	21408.094	19.142
GCP3	8038814.651	214717.75	14.311
GCP4	8037451.373	214858.638	2.537
GCP5	8038355.317	214805.095	19.213
GCP6	8037355.108	214840.794	4.785
GCP7	8037355.108	215255.225	21.103
GCP8	8037012.91	214830.416	2.192
GCP9	8036771.245	215366.856	18.949
GCP10	8036737.822	215054.076	1.55
GCP 12	8036460.162	215149.428	1.907
GCP 13	8037381.029	215843.074	31.91
GCP 14	8037114.414	215510.039	55.841
GCP 15	8036852.201	216127.994	42.138
GCP 16	8036431.659	215629.006	45.629
GCP 17	8035838.607	215901.464	21.044
GCP 18	8035903.399	215199.336	19.636

Data acquired was processed through the standard Kahuto workflows for both LiDAR and Imagery, which includes checks to ground control.

The photogrammetry process using arbitrary CRS as a method enabled us to process photogrammetry in Horizontal Projection: WGS 84 / UTM zone 59 South, Vertical: MSL (Local). Summary of processing photogrammetry below which ground control points

Quality Report

PIX4Dmatic v1.81.1

PIX4D

Camera	DJI_ZenmuseP1_35.0_8192x5460
Area covered	2.776 km²
Average GSD	2.1 cm
Project CRS	WGS 84 / UTM zone 59S + MSL height - EPSG:32759+5714 [Geoid height ~ +63.940 m]
Dense point count	586,326,045

Quality check

Matches	Median of 6745 matches per calibrated image	✓
Dataset	100% calibrated (2380/2380 images), 1 calibration block	✓
Camera optimization	0.23% relative difference between initial and optimized internal camera parameters	✓
GCPs	17 GCPs, Mean RMS position error 0.005 m / Sigma 0.005	✓
ATPs	4536322 ATPs	

Ground control points (GCPs)

Label	Position error			Reprojection error [px]	Accuracy		Verified/ Marked
	X [m]	Y [m]	Z [m]		X/Y [m]	Z [m]	
GCP1	-0.000	0.000	0.001	0.4	0.020	0.020	19/19
GCP2	0.002	-0.001	-0.002	0.3	0.020	0.020	18/18
GCP3	0.002	0.001	0.001	0.2	0.020	0.020	25/25
GCP4	0.006	-0.006	-0.003	0.2	0.020	0.020	23/23
GCP5	-0.003	-0.003	0.002	0.2	0.020	0.020	18/18
GCP6	-0.000	0.002	0.001	0.2	0.020	0.020	22/22
GCP7	-0.009	0.010	0.004	0.1	0.020	0.020	24/24
GCP8	-0.003	-0.007	0.000	0.2	0.020	0.020	15/15
GCP9	0.015	-0.007	0.005	0.5	0.020	0.020	23/23
GCP10	-0.009	0.003	0.000	0.2	0.020	0.020	16/16
GCP12	-0.003	0.001	-0.000	0.3	0.020	0.020	21/21
GCP13	0.001	0.002	-0.002	0.3	0.020	0.020	22/22
GCP14	-0.004	-0.006	-0.005	0.5	0.020	0.020	20/20
GCP15	0.006	0.005	-0.006	0.4	0.020	0.020	21/21
GCP16	0.003	0.007	-0.003	0.5	0.020	0.020	17/17
GCP17	0.000	0.002	-0.003	0.4	0.020	0.020	21/21
GCP18	0.000	-0.003	0.003	0.3	0.020	0.020	26/26
Min	-0.009	-0.007	-0.006	0.1			
Max	0.015	0.010	0.005	0.5			
Mean	0.000	-0.000	-0.000	0.3			
Median	0.000	0.001	0.000	0.3			
Sigma	0.006	0.005	0.003	0.1			
RMS	0.006	0.005	0.003	0.3			

The Photogrammetry quality report indicates a strong and reliable dataset. A large area of **2.776km²** was processed using a **DJI Zenmuse P1** camera, achieving an **average GSD of 2.1 cm**.

Calibration quality is excellent, with **100% of images successfully calibrated (2380/2380)** and a **median of 6745 keypoint matches per calibrated image**, confirming strong image overlap and feature detection.

Geospatial accuracy is high:

- **17 Ground Control Points (GCPs)** were used, achieving a **mean RMS error of only 0.005 m** with **sigma = 0.005**, demonstrating very tight alignment between the photogrammetric model and ground truth.
- Camera optimization results show a minimal **0.23% relative difference**, indicating stable

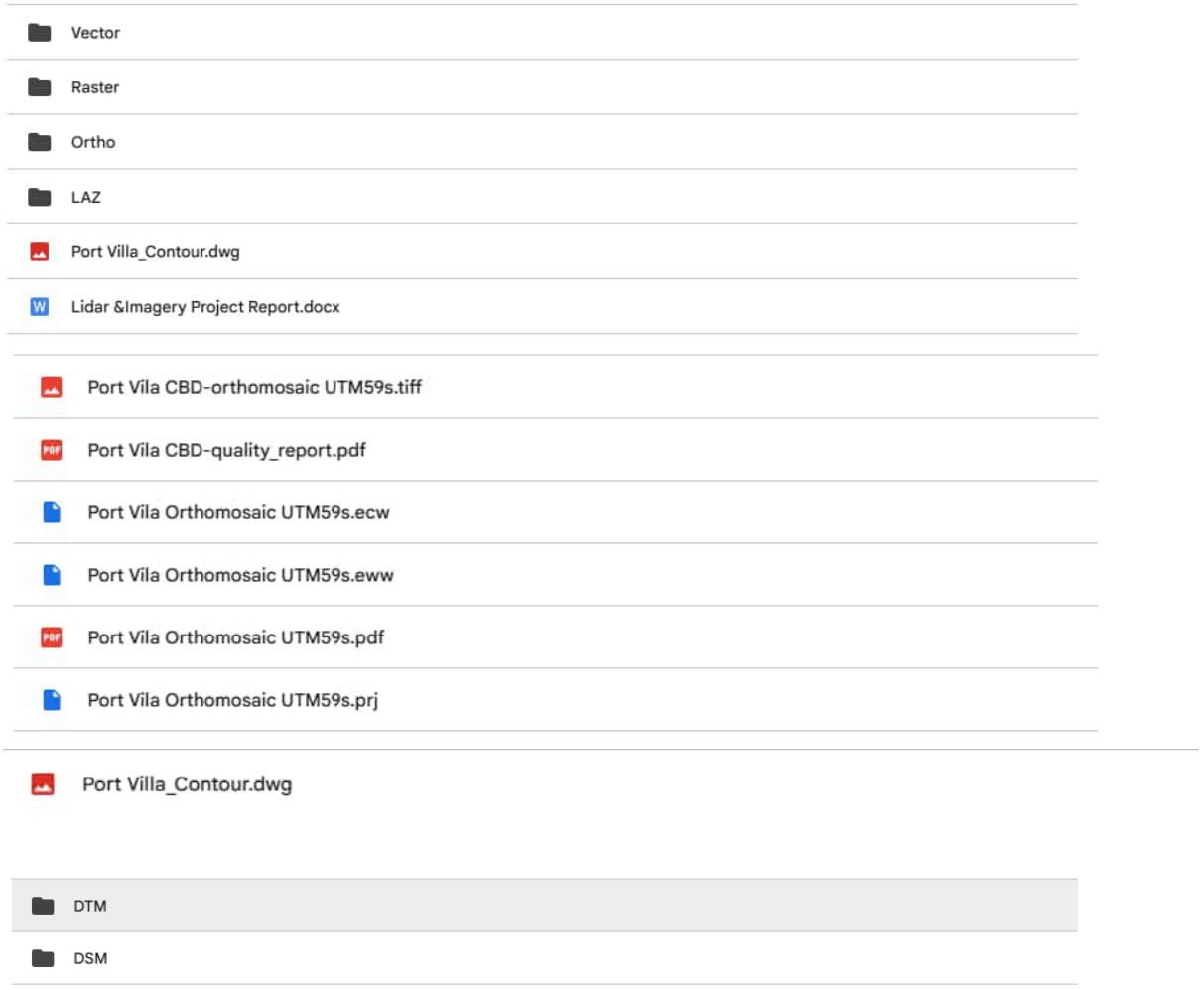
and accurate internal camera parameter estimation.

The dense point cloud contains **586,326,045 points**, reflecting high detail and robust reconstruction.

CAD

A total of five sheets were determined to be sufficient for this project because the overall scope and level of detail can be clearly communicated within that layout. The design elements follow standard conventions and do not require additional breakdowns or enlarged views. This approach ensures all required information is included while maintaining clarity, consistency, and an efficient review process.

The following deliverables were created for the client as well as PDF plans.
Some examples of the deliverables are shown below.

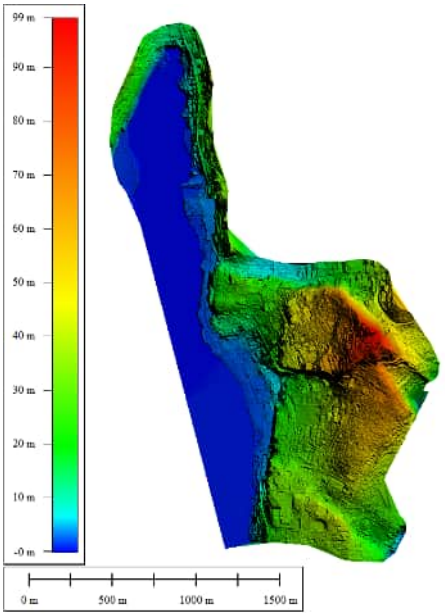


Some examples of the product deliverables are shown below.

Ortho (TIFF,ECW,PDF)



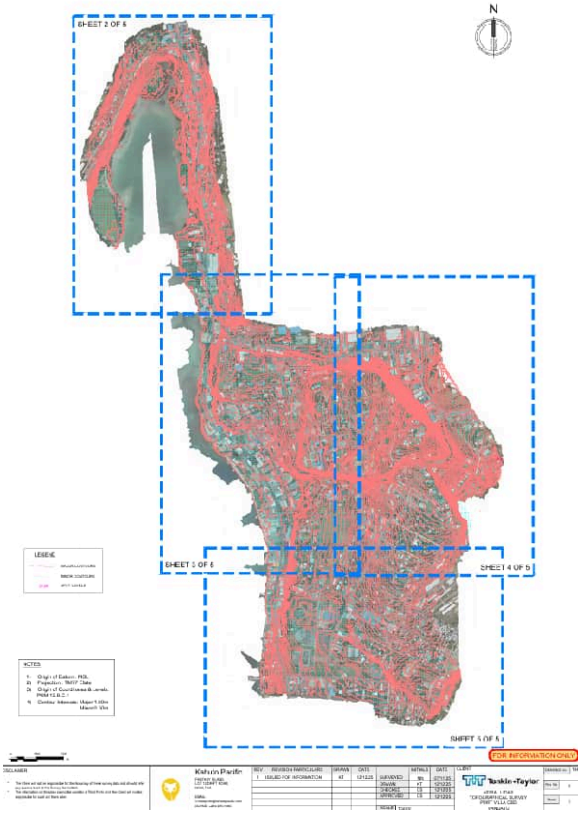
DTM (TIFF,DWG,PDF)



Contours (DWG,DXF) *also provided in final CAD plan



CAD (PDF 5 sheets,DWG)



Kahuto Pacific thank you for involving us in your project.

Chris Saili



Managing Director
Kahuto Investments Pte Ltd

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KAHUTO PACIFIC

SHEET 2 OF 5

SHEET 3 OF 5

SHEET 4 OF 5

SHEET 5 OF 5

LEGEND

14.7 m CONTOURS

22.21 SPOT LEVELS

NOTES

1) Origin of Datum : MSL
2) Projection : TM77 Efate
3) Origin of Coordinates & Levels: PSM 12.9.C.1
4) Contour Intervals: 0.50m

0 125 250 m

FOR INFORMATION ONLY

DISCLAIMER

* The Client will not be responsible for the Accuracy of these survey data and should refer any queries back to the Survey Consultant.
* The information on this plan cannot be used by a Third Party and the Client will not be responsible for such act there after.

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REV	REVISION PARTICULARS	DRAWN	DATE
1	ISSUED FOR INFORMATION	KT	12/12/25
2	ISSUED FOR INFORMATION	KT	10/02/2026

	INITIALS	DATE
SURVEYED	NN	07/11/25
DRAWN	KT	12/12/25
CHECKED	CS	12/12/25
APPROVED	CS	12/12/25

SCALE: 1:5000

CLIENT

Tonkin+Taylor

AERIAL LIDAR
TOPOGRAPHICAL SURVEY
PORT VILLA CBD
VANUATU

DRAWING No. 1049

Rev No 2

Sheet 1

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KAHUTO PACIFIC



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LEGEND

14.7 m — CONTOURS

22.21 — SPOT LEVELS

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REV	REVISION PARTICULARS	DRAWN	DATE
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2	ISSUED FOR INFORMATION	KT	10/02/2026

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APPROVED	CS	12/12/25
SCALE: 1:2000		

CLIENT

Tonkin+Taylor

AERIAL LIDAR
TOPOGRAPHICAL SURVEY
PORT VILLA CBD
VANUATU

DRAWING No. 1049

Rev No 2

Sheet 3

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KAHUTO PACIFIC



LEGEND

14.7 m — CONTOURS

22.21 — SPOT LEVELS

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SCALE: 1:2000

CLIENT

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AERIAL LIDAR
TOPOGRAPHICAL SURVEY
PORT VILLA CBD
VANUATU

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Sheet 4

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LEGEND

14.7 m — CONTOURS

22.21 — SPOT LEVELS

NOTES

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3) Origin of Coordinates & Levels: PSM 12.9.C.1
4) Contour Intervals: 0.50m

0 12.5 25 m

FOR INFORMATION ONLY

ANY OBJECTS OUT SIDE OF THE DRG. BORDER TO BE REMOVED BEFORE PUBLISHED

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				APPROVED	CS	12/12/2025
				SCALE:	1:2000	

CLIENT

Tonkin+Taylor

AERIAL LIDAR
TOPOGRAPHICAL SURVEY
PORT VILLA CBD
VANUATU

CONSULTANT/CONTRACTOR:-

APPROVED BY : - CS

DRAWING No. 1049 | Original | Rev No 2 | Sht No 5

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50 m 250 m 450 m



Together we create + sustain a better world