

# R-2582A Robinson 2 Borrow Pit

## Summary of Project Area, Survey, & Flight

### Project

- Description: CON - US 158/NC 46 FROM I-95/NC 46 IN ROANOKE RAPIDS TO SR 1312 (ST. JOHN CHURCH ROAD) IN NORTHAMPTON COUNTY. ROBINSON 2 PIT ORIGINAL FLIGHT

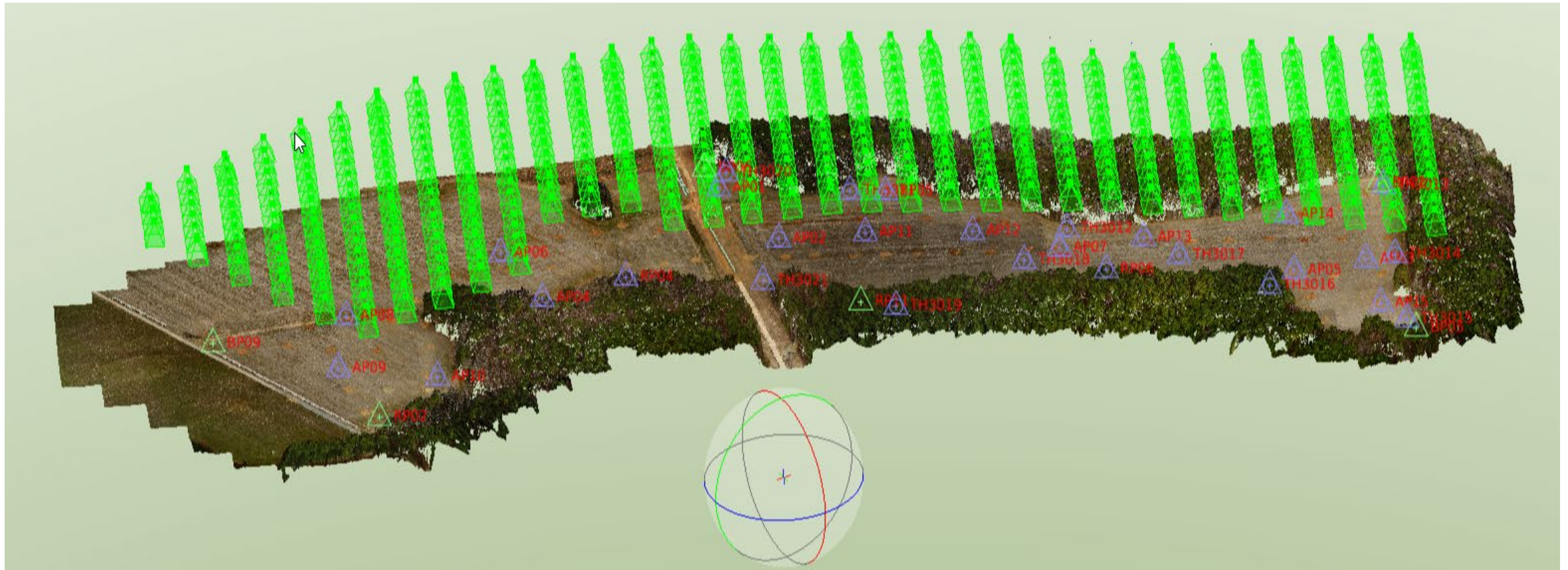
### Image Acquisition

- ucs-744r2p, DOP 02/04/20, DJI Inspire 2 Drone, DGI Zenmuse X4s camera, FL 8.8 mm, flying height 400ft AMGL
- flown short axis with a south/north direction of flight with nominal 0.11 ft GSD
- weather conditions were slightly overcast and windy
- manned aircraft flight – cs-744, DOP 01/28/20, Vexcel UltraCam Eagle M3 camera

### Survey/Control

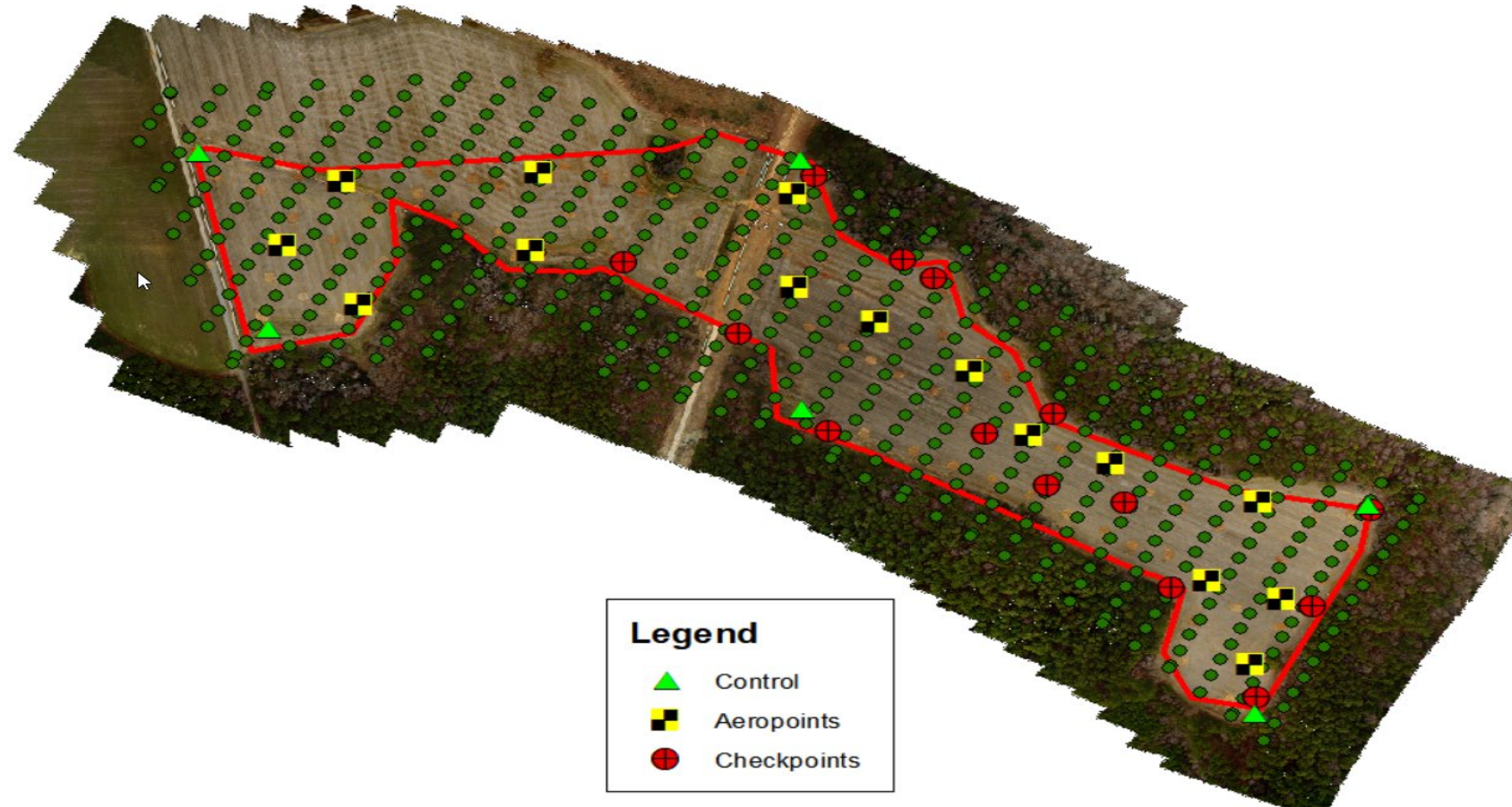
- GNSS exposure station data available via GeoCue Loki ASP system
- horizontal datum NAD 1983 (Conus), vertical datum NAVD 88, geoid G09NC, centroid localization point
- no control issues

# Project Graphic with Image Background



- February 04, 2020 UAS Flight (UCS-744R2P)
- Short axis (south/north) oriented nadir flight lines
- 498 images (planned 80% forward and side overlap)

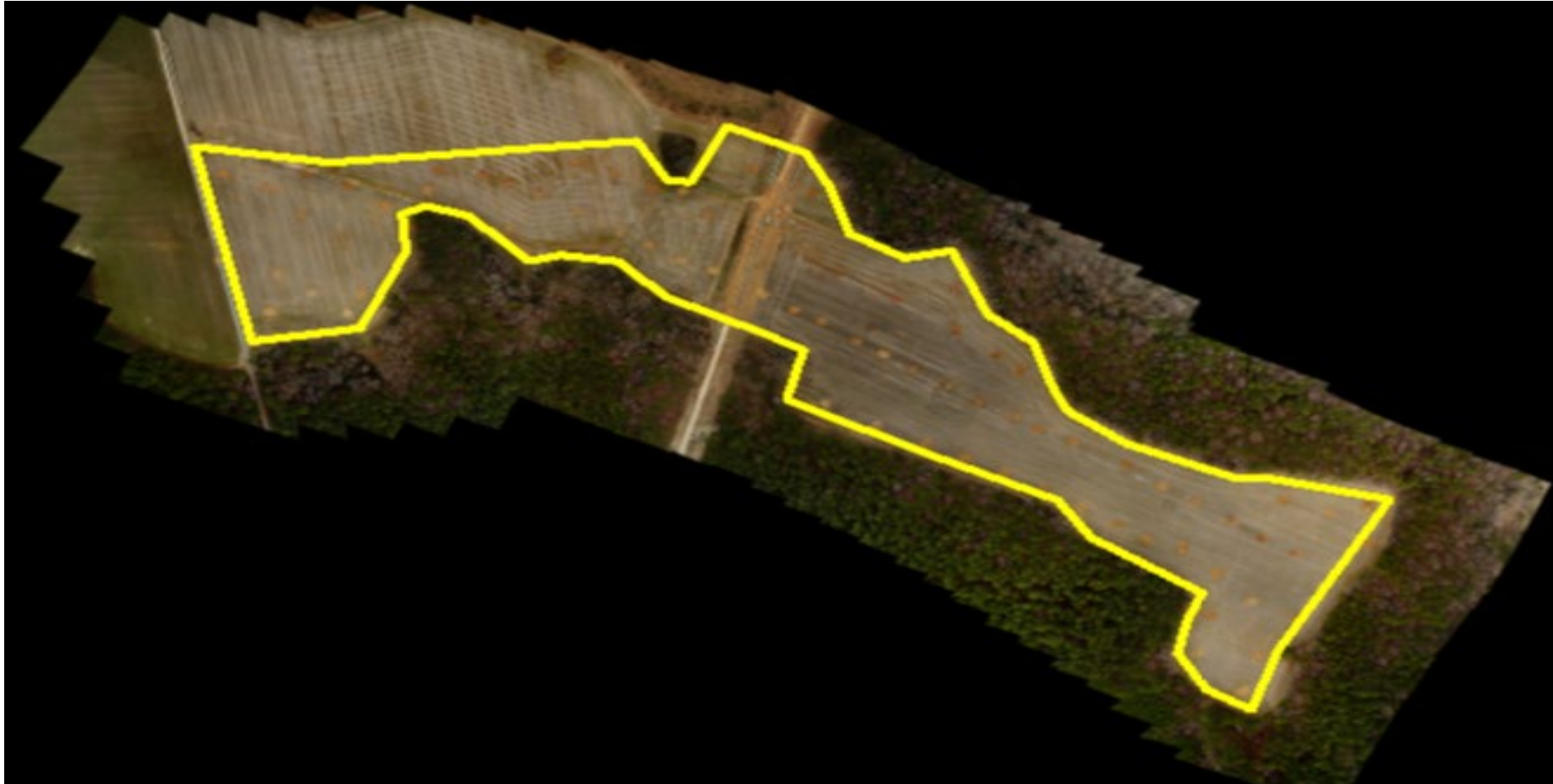
# Ground Control Points and Checkpoints Locations



- Orthophoto with 6 field surveyed ground control points, 29 independent checkpoints consisting of Aeropoints and field surveyed checkpoints, exposure stations, & original project boundary

# Classified Ground Boundary

*(from 02-04-20 UAS Flight)*



**Classified Ground Boundary = 38.6 Acres**

# Image Alignment Results

## Independent Checkpoint Accuracy 6 GCP Only

	Point ID	X error (ft)	Y error (ft)	Z error (ft)
<b>No. Points =</b>		29	29	29
<b>Min (ft) =</b>		-0.071	-0.090	-0.177
<b>Max (ft) =</b>		0.154	0.090	0.193
<b>Mean (ft) =</b>		0.042	0.004	0.009
<b>Std Dev (ft) =</b>		0.061	0.048	0.090
<b>RMSE (ft) =</b>		0.073	0.047	0.089
<b>FVA (ft) =</b>				0.174
<b>RMSE R (ft) =</b>		0.087		
<b>Case 1 95% CE(ft) =</b>		0.150		
<b>Case 2 ~ CE(ft) =</b>		0.147		

## Independent Checkpoint Accuracy 6 GCP + Exposure Stations

	Point ID	X error (ft)	Y error (ft)	Z error (ft)
<b>No. Points =</b>		29	29	29
<b>Min (ft) =</b>		-0.051	-0.076	0.028
<b>Max (ft) =</b>		0.137	0.067	0.118
<b>Mean (ft) =</b>		0.026	0.002	-0.027
<b>Std Dev (ft) =</b>		0.051	0.039	0.080
<b>RMSE (ft) =</b>		0.056	0.038	0.084
<b>FVA (ft) =</b>				0.164
<b>RMSE R (ft) =</b>		0.068		
<b>Case 1 95% CE(ft) =</b>		0.118		
<b>Case 2 ~ CE(ft) =</b>		0.116		

No GNSS Block Shift applied

# Dense Point Cloud Accuracy Results

## Vertical RMS Summary Statistics for Check Points using Classified Point Cloud

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the classified Point Cloud data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.062
Minimum (ft.)			-0.227
Mean (ft.)			-0.063
Standard Deviation (ft.)			0.083
RMSE (ft.)			0.103
95% Accuracy (ft)			0.203
99.74% Accuracy (ft)			0.310

126,092,484 points for 38.6 acres

Classified Point Cloud Boundary  
from 02-04-20 UAS Flight

Point Cloud Generation Process is fully automated so whatever is shown in imagery is captured

# 1-Foot DEM Accuracy Results

## Vertical RMS Summary Statistics for Check Points using 1-foot DEM

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the 1-foot DEM data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.076
Minimum (ft.)			-0.235
Mean (ft.)			-0.057
Standard Deviation (ft.)			0.083
RMSE (ft.)			0.102
95% Accuracy (ft)			0.200
99.74% Accuracy (ft)			0.306

3,225,486 points for 38.6 acres

Classified Point Cloud Boundary  
from 02-04-20 UAS Flight

Point Cloud Generation Process is fully automated so whatever is shown in imagery is captured

# 2.5-Foot DEM Accuracy Results

## Vertical RMS Summary Statistics for Check Points using 2.5-foot DEM

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the 2.5-foot DEM data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.094
Minimum (ft.)			-0.267
Mean (ft.)			-0.049
Standard Deviation (ft.)			0.096
RMSE (ft.)			0.106
95% Accuracy (ft)			0.208
99.74% Accuracy (ft)			0.318

528,548 points for 38.6 acres

Classified Point Cloud Boundary  
from 02-04-20 UAS Flight

Point Cloud Generation Process is fully automated so whatever is shown in imagery is captured



## Vertical RMS Summary Statistics for Check Points using UASMaster Stereo View at Nadir

The following table provides a summary of the vertical RMS statistics for all check point measurements captured in stereo models using same strip adjacent image pairs (angle set to 80 degrees). The narrow 8.5° incident angle between same strip adjacent images with a base to height ratio of 0.15 likely will not yield the best elevation accuracy results.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.868
Minimum (ft.)			-0.588
Mean (ft.)			0.056
Standard Deviation (ft.)			0.273
RMSE (ft.)			0.274
95% Accuracy (ft)			0.538
99.74% Accuracy (ft)			0.823

## Vertical RMS Summary Statistics for Check Points using UASMaster Stereo View at 60 Degrees

The following table provides a summary of the vertical RMS statistics for all check point measurements using same strip alternate image pairs (60% forward overlap). A wider 17° incident angle between same strip alternate images with a base to height ratio of 0.30 should yield improved elevation accuracy results.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.122
Minimum (ft.)			-0.400
Mean (ft.)			-0.079
Standard Deviation (ft.)			0.119
RMSE (ft.)			0.141
95% Accuracy (ft.)			0.277
99.74% Accuracy (ft.)			0.424

# Summary of Earthwork Quantities

*(Classified Ground Boundary from 02-04-20 UAS Flight)*

R-2582A Robinson Pit 2 Cut Quantities for 38.60 Acre Terrain Data Boundary

(as Compared to Original DTM collected from Manned Aircraft Mission)

Comparison DTM	Mission Date	Point Spacing (ft)	Voided Areas Excluded	Cut (cubic yards)
UAS Mission UCS-744R2P	02/04/2020	2.5	No Void Areas	890.381
UAS Mission UCS-744R2P	02/04/2020	1	No Void Areas	1010.253



# Manned Flight DTM Accuracy Results

## Vertical RMS Summary Statistics for Check Points using Manned Flight DTM

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the Manned Flight DTM data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.410
Minimum (ft.)			-0.198
Mean (ft.)			0.066
Standard Deviation (ft.)			0.153
RMSE (ft.)			0.164
95% Accuracy (ft)			0.322
99.74% Accuracy (ft)			0.493

Manned flight DTM has break lines and a 10' grid spacing for points

## Vertical RMS Summary Statistics for Check Points using ISDM Stereo View at 60 Degrees

The following table provides a summary of the vertical RMS statistics for all check point stereoscopic measurements using a base to height ratio near 0.30 for manned flight stereo pairs with a 60% overlap.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			29
Maximum (ft.)			0.116
Minimum (ft.)			-0.340
Mean (ft.)			-0.066
Standard Deviation (ft.)			0.106
RMSE (ft.)			0.123
95% Accuracy (ft)			0.242
99.74% Accuracy (ft)			0.370

## Summary Table of RMSE & 95% FVA

Platform	Camera Size & Type	No. of Images	Date of Photography	Product	No. of Independent Check Points	RMSE Z (ft)	FVA (ft)
UAS	20 Mpixel non-metric	498	2/4/2020	AT (GCP only)	29	0.089	0.174
				AT (GCP+ GNSS)	29	0.084	0.164
UAS	20 Mpixel non-metric	498	2/4/2020	2 Image Stereo Measurement (80% FOL)	29	0.274	0.538
				2 Image Stereo Measurement (60% FOL)	29	0.141	0.277
Manned Aircraft	450 Mpixel metric	8	1/28/2020	2 Image Stereo Measurement (60% FOL)	29	0.123	0.242
UAS	20 Mpixel non-metric	498	2/4/2020	Dense Point Cloud	29	0.103	0.203
				1 feet DEM*	29	0.102	0.200
				2.5 foot DEM*	29	0.106	0.208
Manned Aircraft	450 Mpixel metric	8	1/28/2020	DTM* ( breaklines & 10 foot spaced points)	29	0.164	0.322

\* Standard elevation products offered by the Photogrammetry Unit

# R-2582A Robinson 2 Borrow Pit

## Conclusions

- Target RMSE accuracy values are an X and Y (Easting & Northing) of 0.12 ft and Z (Elevation) of 0.18 ft. The image alignment (aerotriangulation) results using 6 ground control points and GNSS PPK camera station positions yielded RMSE values of 0.056 ft in X, 0.038 ft in Y, and 0.084 ft in Z, all well below the target accuracy values.
- The 2 image stereo measurements at 60% forward overlap on the UAS imagery and the Manned flight imagery have similar RMSE and FVA values on this project, however, that is not always the case. Testing on other UAS project imagery indicates 2 UAS image stereo measurements is not reliably accurate for earthwork determination.
- The 1 ft DEM contains 610% more points than the 2.5 ft DEM, thus making the 2.5 ft DEM file size much smaller and more manageable. With a cut difference of only 119.87 cubic yards between the 1 ft DEM and 2.5 ft DEM over 38.6 acres one can conclude that the 2.5 ft DEM is dense enough data to provide for accurate volumetric calculations and comparisons and the 1 ft DEM is not necessary.
- The 2.5 ft UAS DEM has a lower RMSE Z and FVA than the DTM collected from the Manned flight. The denser 2.5 ft DEM point interval captures the overall terrain better than the break lines and 10 ft point interval of the DTM.
- Since there is a limit to the amount of data that can be input into our CADD software, UAS imagery projects are not ideal for larger mapping areas.
- Projects best suited for utilizing UAS imagery should have cleared ground with little to no vegetation.