QC REPORT ON LIDAR DATA
PRODUCED BY SHARPER SHAPE, INC., FOR
PACIFIC GAS & ELECTRIC COMPANY

PROJECT AREA: WAVE 4
DATE OF LAS DELIVERY REPORT: September 4, 2020

Introduction

Sharper Shape, Inc., (Sharper Shape) is under contract to Pacific Gas & Electric Company (PG&E) to produce an array of remotely sensed data and products, including Light Detection and Ranging (lidar) data, for approximately 800 electric power distribution corridors in wildfire threat areas in California designated Tier 2 and Tier 3. GeoWing Mapping, Inc., (GeoWing) is a subcontractor for Sharper Shape to conduct quality control (QC) for Sharper Shape deliverables. For this project, QC will consist of independent accuracy assessments of the absolute accuracy of the lidar data (LAS v.1.4) to ensure compliance with PG&E standards and with Positional Accuracy Standards for Digital Geospatial Data as published by the American Society for Photogrammetry and Remote Sensing (ASPRS) in 2014.

Project Data Organization

Sharper Shape lidar acquisition and processing domains were designed as areas (polygons) enclosing electric power distribution corridors, termed "circuit areas." PG&E's service area spans Northern and Central California and lidar data acquisition and processing were conducted in Universal Transverse Mercator (UTM) Zone 10 North (WGS84). Processing was also conducted in California State Plane Coordinate System (SPCS) Zones 1 through 5 (NAD83-Epoch 2011). PG&E conducted field operations to develop control survey points necessary for the lidar processing. PG&E also provided coordinates of surveyed points to GeoWing for the QC processing. For delivery, Sharper Shape used California SPCS zones as the organizing structure. For instance, all circuit area polygons and associated lidar data sets and ground control/checkpoints that fell within SPCS Zone 4, were assembled into a delivery package entitled Wide Area Verification Extension (WAVE) area #4, or WAVE4. There are 5 WAVE delivery packages. For this QC report, see Figure 1. (line drawing of California SPCS zone 4, check points, and Zone 4 circuit areas.)

Sharper Shape used PG&E-provided ground survey points to control and process the lidar data and to conduct an internal review of absolute and relative vertical accuracy using ground survey points that were not used in the processing of the lidar data. Sharper Shape's Zone 4 WAVE data processing and results are documented in a report submitted to PG&E entitled "WAVE Report CHIP19 Zone 4" and serves as a reference to this QC report.

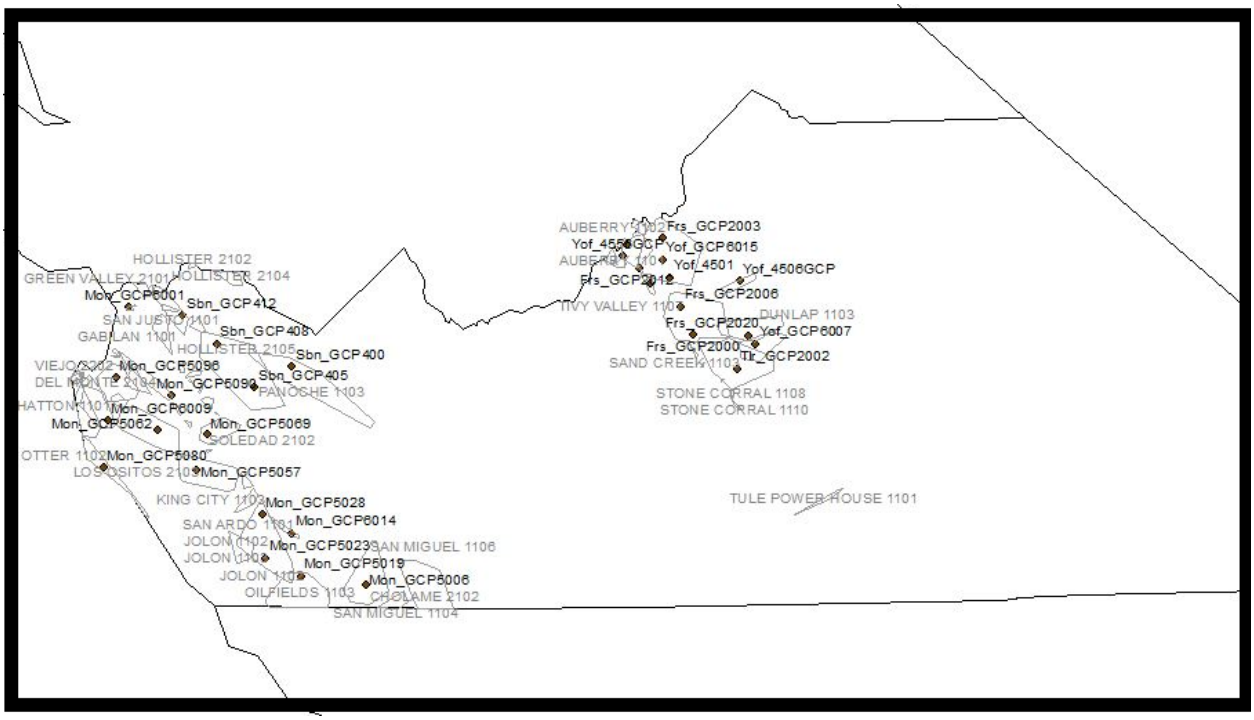

Figure 1. WAVE Zone 4 with circuit areas and checkpoints

QC Data Delivery

Lidar data delivered to GeoWing for QC are a subset of the entire suite of WAVE circuit areas processed by Sharper Shape for PG&E. From among 115 check points used by Sharper Shape to test the lidar data, GeoWing randomly selected 29 check points based upon geographic dispersion in order to provide a representative sample of surveyed points to serve as "true" values for absolute accuracy testing. Following selection of the 29 checkpoints, GeoWing identified the circuit area polygons in which the checkpoints were located. GeoWing provided the list of circuit area polygons and lidar tiles to Sharper Shape which then uploaded the circuit area polygon folders and/or lidar tiles containing the associated lidar data to a file transfer protocol site, s3Browser, making the lidar data available to GeoWing for download and QC.

GeoWing QC Processing

GeoWing's QC procedure for the Sharper Shape project consists of two independent processes that compare a lidar surface to surveyed checkpoints to confirm Sharper Shape's internal QC results. First, the lidar data are loaded into the process, and an elevation surface in the appropriate SPCS zone from the lidar data sets was developed. Second, the 29 randomly selected check points in the same SPCS zone are loaded into the process. Since the circuit area lidar data sets were identified based on the locations of the check points, a lidar surface for each check point was developed. Third, the Z value in the lidar surface at the X-Y location that corresponds to the X-Y location of a check point was determined. The Z-value (elevation) of the lidar surface (in feet) at the locations of all 29 checkpoints were measured and documented on the QC worksheet in preparation for the accuracy testing.

Absolute Vertical Accuracy

Vertical accuracy reporting is designed to meet guidelines established by ASPRS. The statistical model compares the elevations (Z-values) of known ground check points to the Z-values of lidar points at the same X and Y coordinate-values to determine absolute vertical accuracy. For this assessment of vertical accuracy, the statistical analysis uses check points that were established in open areas within which the lidar system had high probability that the sensor will measure the ground surface and could be evaluated at the 95% confidence level.

ASPRS specifies a minimum of 20 test points to adequately assess vertical accuracy. GeoWing has chosen to test 29 check points in non-vegetated areas (NVA). As part of the independent accuracy assessment, a comparison of survey control vertical values versus their corresponding lidar surfaces was conducted (in US Survey Feet) using the respective measurement tools of two different approaches. Table 1 presents side-by-side comparisons of Sharper Shape and GeoWing QC results (see highlighted columns). Column headers “DZm-s” and DZm-g represent the difference in meters between the lidar surface and the surveyed point at the same X-Y location for Sharper Shape (“s”) and for the average of GeoWing’s 2 independent processes (“g”). Sharper Shape values (DZm-s) were excerpted from a tabulation of check points provided by Sharper Shape. “DZf1” and “DZf2” present the results of GeoWing’s measurements of the difference (in feet) between the lidar surface and the surveyed point at the corresponding X-Y location for process #1 and for process #2. GeoWing’s test results were converted from US Survey feet to meters to facilitate direct comparison with Sharper Shape’s results in meters within the framework of ASPRS parameters.

GeoWing’s random sampling of 29 check points produced an RMSEz of 9.99-cm (compared to Sharper Shape’s RMSEz of 9.61-cm for the same 29 checkpoints). In Sharper Shape’s processing of WAVE 4, 115 check points were tested against the lidar surfaces at the locations of those test points. A similar computation on the entire suite of 115 check points yields an RMSEz of 10.76-cm for WAVE 4. See Table 2 for the relevant summary of ASPRS’ Positional Accuracy Standards for Digital Geospatial Data as it pertains to this project.

GeoWing's independent measurement and reporting of error, i.e, RMSE values, were determined to validate Sharper Shape's measurement and reporting of error on the WAVE 4 dataset. Differences between the measured error were not statistically significant and both sets of measurement were found to be within the target accuracy.

Sharper Shape Results		GeoWing Mapping Results				
		Average		Set 1		Set 2
Checkpoint ID	DZm-s	DZm-g	DZf1	DZm1	DZf2	DZm2
Frs_GCP2004	-0.114	-0.169	-0.5531	-0.16859	-0.5571	-0.1698
Frs_GCP2008	0.106	0.101	0.3323	0.101285	0.3333	0.10159
Frs_GCP2009	0.100	0.036	0.1069	0.032583	0.1309	0.039898
Frs_GCP2010	0.111	-0.205	-0.6406	-0.19526	-0.7036	-0.21446
Frs_GCP2011	-0.125	-0.126	-0.4284	-0.13058	-0.4004	-0.12204
Frs_GCP2013	0.144	0.101	0.3148	0.095951	0.3458	0.1054
Frs_GCP2016	0.005	0.009	0.0305	0.009296	0.0285	0.008687
Frs_GCP2019	-0.116	-0.114	-0.3802	-0.11589	-0.3662	-0.11162
Frs_GCP2020	0.035	0.031	0.1059	0.032278	0.0999	0.03045
Mon_GCP5006	-0.004	-0.006	-0.0191	-0.00582	-0.0171	-0.00521
Mon_GCP5007	-0.126	-0.131	-0.4354	-0.13271	-0.4274	-0.13027
Mon_GCP5022	0.099	0.090	0.3009	0.091715	0.2879	0.087752
Mon_GCP5025	0.045	0.039	0.1293	0.039411	0.1293	0.039411
Mon_GCP5057	0.011	-0.025	-0.0806	-0.02457	-0.0846	-0.02579
Mon_GCP5075	-0.008	-0.152	-0.5032	-0.15338	-0.4942	-0.15063
Mon_GCP5091	-0.179	-0.197	-0.6286	-0.1916	-0.6656	-0.20288
Mon_GCP5096	0.099	0.136	0.4629	0.141092	0.4269	0.130119
Mon_GCP6002	-0.153	-0.160	-0.5105	-0.1556	-0.5385	-0.16414
Sbn_GCP401	0.035	0.033	0.1075	0.032766	0.1075	0.032766
Sbn_GCP404	0.091	0.074	0.2473	0.075377	0.2413	0.073548
Tlr_GCP701	0.094	0.081	0.2689	0.081961	0.2649	0.080742
Yof_4002CK	-0.119	-0.047	-0.1617	-0.04929	-0.1457	-0.04441
Yof_4501	0.011	-0.007	-0.0304	-0.00927	-0.0164	-0.005
Yof_4556GCP	0.056	0.012	0.0463	0.014112	0.0303	0.009235
Yof_GCP6009	0.027	0.000	0.0532	0.016215	-0.0558	-0.01701
Yof_GCP6014	0.106	-0.065	-0.1921	-0.05855	-0.2371	-0.07227
Yof_GCP6015	0.089	-0.058	-0.1869	-0.05697	-0.1909	-0.05819
Yof_GCP6017	0.027	0.013	0.0337	0.010272	0.0497	0.015149
Yof_GCP6021	-0.142	-0.100	-0.3365	-0.10257	-0.3175	-0.09677
Sharper Shape RMSEz = 0.096 meters, 9.61 cm						
GeoWing RMSEz = 0.099 meters, 9.99 cm (DZm-g computed mean of 2 GeoWIng tests)						

Table 1. Sharper Shape and GeoWing Mapping Vertical Accuracy Testing

	Absolute Accuracy		
Vertical Accuracy Class (cm)	**RMSEz NVA (cm)**	**NVA at 95% Confidence Level (cm)**	**VVA at 95th Percentile (cm)**
1	1	2	N/A this test
2.5	2.5	4.9	N/A this test
5	5	9.8	N/A this test
10	10	19.6	N/A this test
15	15	29.4	N/A this test

Table 2. from ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)

- RMSEz NVA = 9.61-cm – Meets ASPRS Vertical Accuracy Class (10cm)
- NVA at 95% Confidence = 18.8-cm - Meets ASPRS Vertical Accuracy Class (19.6-cm)
- *Overall - ASPRS Vertical Accuracy Class Met = 10cm*

Absolute Horizontal Accuracy

Current ASPRS standards define absolute horizontal accuracy of aerial lidar data as a function of flying altitude, GNSS positional error, and INS angular error. Utilizing those 3 values and the formula shown on Page A7 (ASPRS, 2014), Sharper Shape developed an approximate horizontal RMSEr for the project using acquisition system configuration parameters and published it in the "WAVE Report CHIP19 Zone 4" report. In addition, PG&E set selected control points and check points on visible features within the point cloud which were able to be distinguished when viewing intensity returns. These included painted stripes, stop bars, and other features visible in the intensity component of the lidar data.

GeoWing's contract with Sharper Shape does not include an extensive assessment of absolute horizontal accuracy. However, due to the importance of horizontal (X-Y) location to the precise positioning of an elevation value (Z) to its corresponding location on a lidar surface, and to ensure the veracity of any vertical accuracy testing performed, GeoWing determined that a random spot check of Sharper Shape's procedure and results of horizontal accuracy testing should be undertaken.

As presented in its "WAVE Report CHIP19 Zone 4" Report, Sharper Shape used intensity values of lidar data, much like GeoWing would use rectified aerial photography, to measure horizontal differences between surveyed paint stripe images, etc., and their surveyed X-Y coordinates. GeoWing reviewed one example of a horizontal test at check point Mon_GCP5094 in circuit area FORT ORD 2106 and lidar tile SS_CASP4_5750000_2133000.laz. GeoWing's testing methodology, also using the intensity image of the lidar data, obtained a difference measurement of 0.06-meter, which supports Sharper Shape's published measurement of 0.05-meter for that point and intensity image. GeoWing concurs with the testing methodology and concurs with the published results of Sharper Shape's horizontal accuracy testing of RMSEr = 10.0-cm (0.10-meters) for 6 check points.

Certification

I, Alan M. Mikuni, PE, being duly registered as a Professional Engineer in and by the State of California (Professional Land Surveyors Act Section 8731), hereby certify that commonly accepted standard practices and methodologies were employed by Sharper Shape for its accuracy assessment, and that the accuracy statistics shown in the Accuracy Section of the "WAVE Report CHIP19 Zone 4" Report have been checked by me using two independent processes, and were found to meet the "Positional Accuracy Standards for Digital Geospatial Data", as specified by ASPRS, 2014.

This data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 (cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy testing conducted by Sharper Shape resulted in RMSEz = 9.61-cm, or 18.8-cm at 95% confidence level.

GeoWing conducted NVA accuracy testing on the same 29 check points resulting in RMSEz = 9.99-cm, or 19.6-cm at 95% confidence level.

Respectfully, submitted,

Alan M. Mikuni, PE
September 11, 2020