Final Survey Report

New Mexico Southeast 2018-2019 QL2 LIDAR

Task Order Name NM_SOUTHEAST_2018_D19

Contract Number G16PC00042

Atlantic Project Number 18079

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Section 1. Executive Summary

1.1 Introduction

In support of the *NM_SouthEast_2018_D19 QL2 LIDAR* project, a geodetic control survey was performed for the collection of quality assurance and quality control (QA/QC) verification points. The importance of this survey was twofold; to ensure homogenous project meeting defined project accuracies, and to "tie" the mapping to existing Continually Operating Reference Stations (CORS) & National Geodetic Survey (NGS) framework used for aerial acquisition. This allows for repeatable measurements for current and future surveying and mapping needs.

The survey encompassed multiple areas of interest (AOI) across the states of New Mexico totaling 23,733.18 square miles of LIDAR. The survey was performed during the period of January 15th through May 17st 2019 with a total of one thousand and thirty nine (1039) measured points. The QA/QC points were subdivided into 3 main categories: non-vegetated, vegetated checkpoints, and Lidar calibration points.

Due to the rugged terrain and isolated pockets of cellular data coverage, Atlantic employed two methodologies' dynamically during the project. Real Time Network – Real Time Kinematic (RTN-RTK) was used when cellular data was available utilizing the Leica Smartnet RTN stations as this provides an instantaneous answer without any additional post processing. When cellular coverage was not available, static Global Navigation Satellite Survey System (GNSS) observations were conducted. These static sessions were postprocessed with the NGS Online Processing User Service (OPUS) using CORS data.

The final required accuracy of the Lidar calibration points (LCP's), QA/QC checkpoints were defined by the specified LiDAR accuracies for this project, the Lidar vertical accuracy is to meet a Root Mean Square Error ($RMSE_Z$) of 10 cm. Typically, QA/QC surveys should be at least three times as accurate as the final products being tested, therefore a $RMSE_{XY}$ of 10.0 cm or less & $RMSE_Z$ of 3.3 cm or less is required. Based on the analysis of the RTN-RTK checkpoints and OPUS network accuracy values, this geodetic control data meets this projects requirement for calibrating and testing the horizontal and vertical accuracies the acquired products.

Section 2. Survey Standards and Equipment

2.1 Introduction

To control the aerial LiDAR for the creation of Quality Level 2 data products, LCP and QA/QC point features were required to have survey coordinates that met the desired USGS 3DEP specifications of the project. The project LCP & checkpoints were dispersed throughout the project to support a strong calibration solution. The survey consisted of the following steps:

1. Identify checkpoint & control proposed locations
2. GNSS survey of localized project control points
3. Evaluate the integrity of the localized project control points
4. GNSS survey all new and unknown LCP & checkpoint location
5. Assess the quality of all LCP & checkpoint computed coordinates through data processing.

2.2 Applicable Standards

The accuracy standards for the QA/QC survey is to be approximately three times as accurate as the Lidar which required a vertical $RMSE_Z$ of 10 cm in non-vegetated areas. Although not specifically tested, the Lidar horizontal accuracy is defined to comply with the "compiled to meet" statement of having a $RMSE_R$ of 60cm or less. Therefore, the accuracy for the QA/QC survey was defined to have a horizontal $RMSE_R$ of <2cm and a $RMSE_Z$ of <3cm to meet and exceed project requirements.

2.3 Datum and Coordinate Systems

All monumented survey control coordinates are reported in Universal Transverse Mercator (UTM) Zone 13 North for horizontal (NAD83) 2011 Epoch of 2010.0000 values and North American Vertical Datum of 1988 (NAVD88) utilizing Geoid model 2012 B (GEOID12B) for vertical values.

2.4 Survey Equipment and Target Material

The following survey equipment was utilized to collect the survey coordinates:

- Trimble GNSS R8 GPS Receiver SN 46391-22449
- Trimble GNSS R10 GPS Receiver SN 5739470192
- Trimble GNSS R10 GPS Receiver SN 5739470190
- Topcon GNSS Hiper GD SN 123445678
- Trimble Tsc-2 Data Collector SN 59100-00

Section 3. Survey and Methodology

3.1 Real Time Network Survey – Real Time Kinematic

RTN-RTK use is a standard throughout the Geo-Spatial industry and was chosen to be the most efficient way to execute this survey when cell phone coverage was available. The RTN networks utilized consist of a system of established GNSS receivers that transmits real-time corrections which are sent to the GNSS rover receiver via cellular connections. The internal accuracy for the fixed ambiguity solutions pertaining to the RTN-RTK network results in a repeatable accuracy of <2cm horizontally and <3cm vertically at the 95% confidence level. All QA/QC points were surveyed utilizing a 2-meter rod leveled over each point coupled with Trimble GNSS receivers using the RTN network. The GNSS receiver is configured to log data at 1 Hz with an update rate of 10Hz, and at 10° degrees' mask at a collection rate of 180 seconds or better. During collection, the field technician monitored standard field criteria to optimize each observation. These field criteria include but is not limited to: number of SV's, PDOP, RMS, and status of ambiguity i.e. "fixed" or "float". RTN-RTK Root Mean Square values and digital field notes can be found in a separate appendix document - *18079_Survey_Report_Appendix.pdf*

In instances where cell phone coverage was not available, RTN-RTK was not an option and static GNSS observations were performed. Similar to RTN-RTK acquisition, a GNSS receiver was positioned with a fixed height tripod over the point and data was collected for a minimum of 30 minutes. These observations were compiled, processed and constrained in a GNSS static network. A GNSS static network objective is to "tie" a series of survey control either preexisting or newly set through simultaneous measurements of three-dimensional GNSS baseline vectors each treated as a separate distance observation and adjusted as part of a trilateration network typically forming a closed polygon

3.2 QA/QC Survey Points

To initially control the Lidar during the calibration phase of production, calibration survey points were required. The LCP's were strategically positioned throughout the project area of interest. These LCP's are located on hard to semi-hard relatively surfaces with flat or moderate slope to allow for a good sampling of ground surface types where the Lidar reflectivity would yield a good range.

To test the vertical accuracy of the Lidar point cloud, Lidar checkpoints were surveyed and used in an independent verification process, post calibration. These check points were collected in two different categories: Non-Vegetated Accuracy (NVA) and Vegetated Vertical Accuracy (VVA). Checkpoints serve to analyze or "ground truth" the accuracy of the LIDAR return with respect to surfaces types found within the project area of interest.

Figures 1-3 displays the survey collection of two hundred forty-one (241) Lidar calibration points, four hundred sixty-four (464) NVA, and three hundred thirty-four (334) VVA checkpoints. Final point coordinates summary, photographs of the LCP's, checkpoints, observation digital Field notes, and static session forms can be found in the separate appendix document.

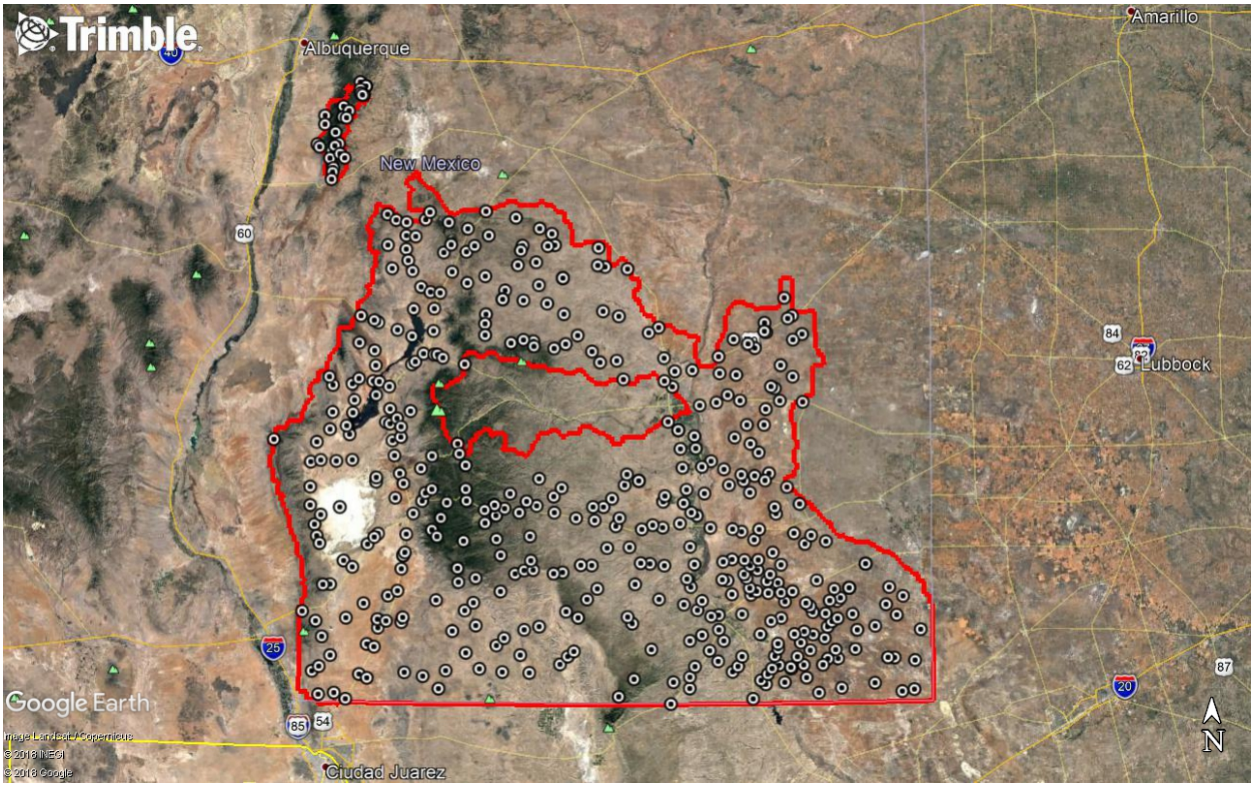

Figure 1 - LCP SURVEY LAYOUT 1

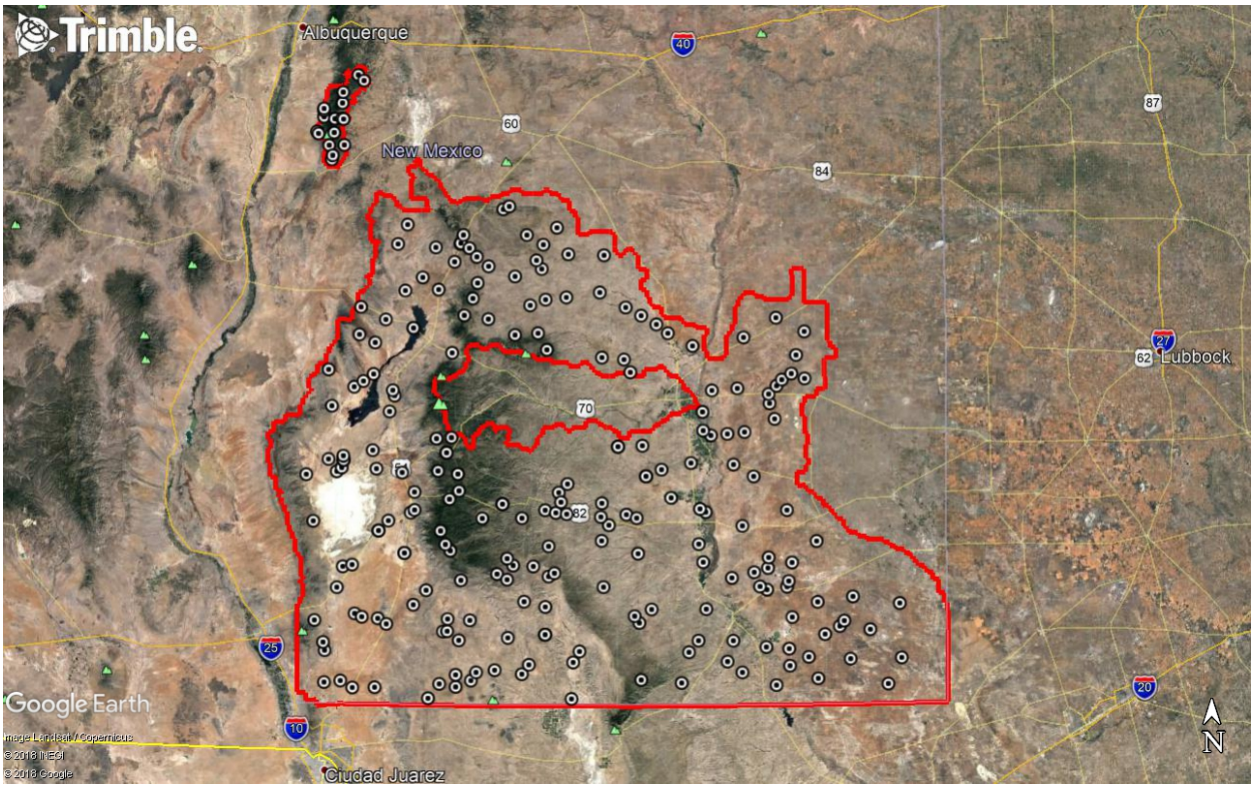

Figure - 2 - NVA SURVEY LAYOUT

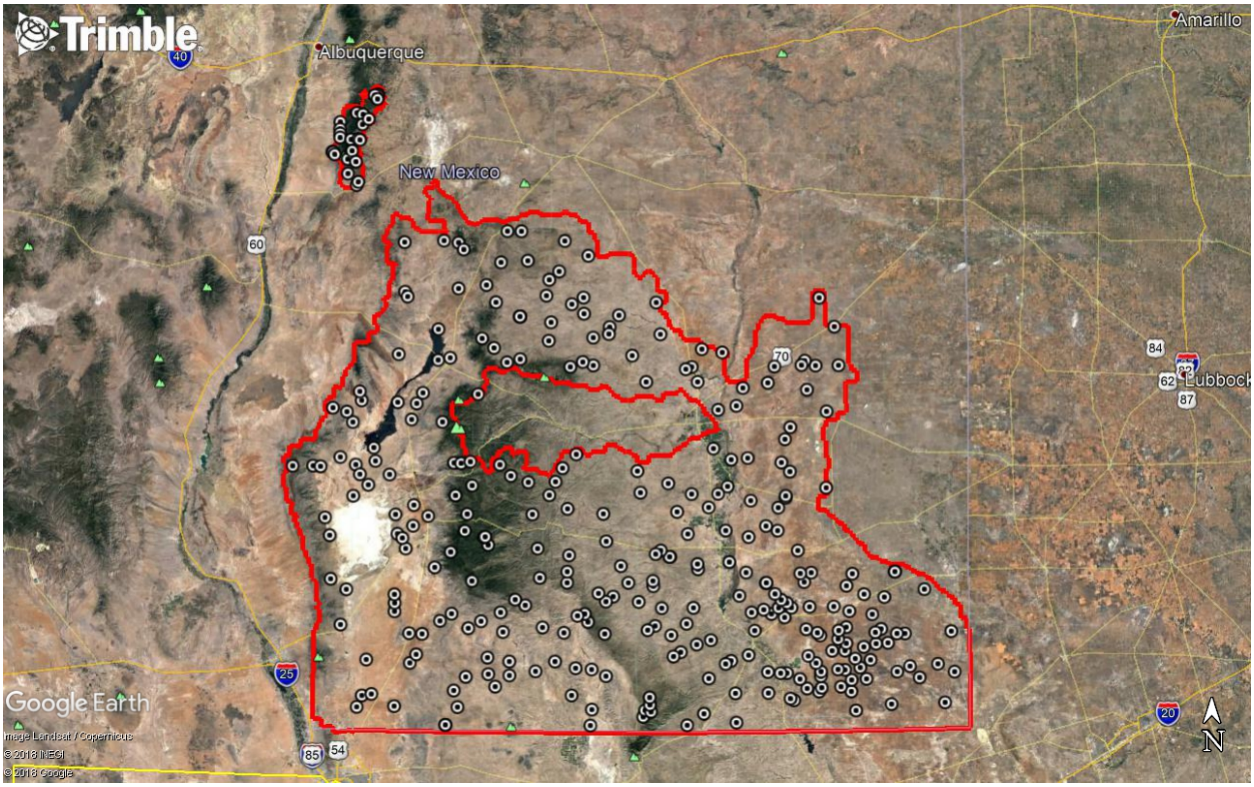

Figure - 3 - VVA SURVEY LAYOUT

3.3 QA/QC Data Analysis

The advantages of using the RTN-RTK survey methodology is obtaining a real-time answer along with an estimate of its accuracy. However, to verify the system integrity and to provide a definitive check, Atlantic performs additional survey processes. Prior to the QA/QC survey, seven (7) new survey verification points were set, statically observed, and processed using the National Geodetic Survey's (NGS) On-Line Positioning User Service (OPUS). OPUS uses a robust 3D least squares algorithm utilizing CORS within the vicinity of the survey point to provide a coordinate along with many metrics on the accuracy. The purpose of these points is to have a measured established coordinate which can be compared to the RTN-RTK coordinates. During each daily survey session, at least two (2) control monument were occupied and compared with the OPUS network adjusted values. If the comparisons were within acceptable tolerances (good repeatability) than the GNSS unit and the system integrity was functioning properly.

To further verify the RTN-RTK data, observed coordinates for each checkpoint, and LCP were transferred into Trimble Business Center software for QA/QC checks. During the analysis, the horizontal and vertical RMS values for each vector line between the RTN base and survey point were reviewed to ensure that they are within acceptable limits.

For all static observations, the processing results and accuracy metrics are reviewed via Grafnet fully constrained network solution report. All GNSS networks were constrained to established CORS stations within a reasonable distance to the project AOI's. If the vector residuals or observation measurements resulted in RMSE values the data would have been reobsevered, however no reobservations were

required. All OPUS solutions, Grafnet network reports, daily comparisons, and the QC observations can be found in a separate appendix document. - *18079_Survey_Report_Appendix.pdf*.

Section 4. Accuracy

4.1 Summary of Target Accuracies

The accuracy of the target locations can be defined multiple ways due to the methods for how each type of targets were derived. The accuracy of this survey was based on the analysis of the RTN-RTK final ground control checks against established project control values With regards to the 1cm+05ppm (horizontally) and 2cm+1.0ppm (vertically) internal accuracy and repeatability of the RTN-RTK network the survey performed by Atlantic meets the project accuracy criteria required to support the mapping products. full Network OPUS accuracy report along with LCP/checkpoint QAQC report can be found in *18079_Survey_Report _Appendix.pdf.*

Section 5. Custody Transfer Assurance

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