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December 8, 2017

Craig Hale
Spatial Technologies Project Manager
Southern Nevada Water Authority / Las Vegas Valley Water District
100 City Parkway
Suite 700
Las Vegas, NV 89106

RE: SNWA / DCP LiDAR Project

Dear Mr. Hale,

It is a pleasure for Merrick & Company ("Merrick") to provide the Southern Nevada Water Authority ("SNWA") with an outline summarizing the required Scope Of Work (SOW) and proposed Lump Sum Fees to meet the needs of SNWA and the Desert Conservation Program ("DCP"). Said outline follows:

- Project area
  - Approximately 289.74 square miles
    - 289 PLSS section-formatted tiles (full)
  - SNWA
    - Approximately 259.12 square miles
      - 259 PLSS section-formatted tiles (full)
      - Five (5) non-contiguous project areas
  - DCP
    - Approximately 58.38 combined square miles
      - Virgin River Area OF Interest (AOI) represents approximately 54.21 square miles
        - 54 PLSS section-formatted tiles (full)
          - Converted from client-provided Esri shapefile (*Virgin_River_Lidar_SA*)
      - Muddy River AOI represents approximately 4.17 square miles
        - Extent of client-provided Esri shapefile (*Muddy_river_LiDAR*)
        - 8 PLSS section-formatted tiles (combination of full and partial)
- LiDAR-only acquisition
  - SNWA
    - USGS **QL2** specifications
      - ≥2ppsm ANPD (Aggregate Nominal Point Density)
      - ≤0.71m ANPS (Aggregate Nominal Point Spacing)
  - DCP
    - USGS **QL1** specifications
      - ≥8ppsm Aggregate Nominal Point Density (ANPD)
      - ≤0.35m Aggregate Nominal Point Spacing (ANPS)
  - Fixed-wing platform
  - Optech Galaxy

- Per USGS-NGP Lidar Base Specifications, Techniques and Methods 11–B4, Version 1.2, November 2014 (TM11-B4)
  - http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf
- Acquisition area(s) includes 100m buffer added to meet TM11-B4
- Vertical accuracy (absolute NVA)
  - ≤10.0cm $RMSE_Z$
  - ≤19.6cm at the 95% confidence level ($Accuracy_Z$)
- Relative accuracy
  - ≤6cm Smooth surface repeatability
  - ≤8cm $RMSD_Z$
  - ±16cm maximum difference

❖ LiDAR checkpoint survey
- **Performed by SNWA surveyors**
- Minimum standards as outlined in TM11-B4 / ASPRS Positional Accuracy Standards for Digital Geospatial Data (EDITION 1, VERSION 1.0. - NOVEMBER, 2014)
  - http://www.asprs.org/a/society/committees/standards/ASPRS_Positional_Accuracy_Standards_Edition1_Version100_November2014.pdf
- Estimate 60 checkpoints total (minimum)
  - 25 Non-vegetated Vertical Accuracy [NVA] checkpoints
    - ±5 checkpoints per separated individual project area
  - 15 Vegetated Vertical Accuracy [VVA] checkpoints
    - ±3 checkpoints per separated individual project area
  - 20 independent (NVA) checkpoints to support the LIDAR calibration task
    - ±4 checkpoints per separated individual project area
- Checkpoints are spatially distributed across the project area(s)
- Assumed projection, datums and units
  - SNWA
    - Projection – **Nevada State Plane Coordinate System, East Zone (FIPS 2701)**
    - Horizontal Datum - North American Datum of 1983 (NAD 83), National Adjustment of 2011 (NA2011) (epoch 2010.00)
    - Vertical Datum – North American Vertical Datum of 1988 (NAVD 88); using the latest NGS-approved geoid (GEOID12B) for converting ellipsoid heights to orthometric elevations
    - Units – **U.S. Survey Foot**
  - DCP
    - Projection – **Universal Transverse Mercator (UTM), Zone 11 North**
    - Horizontal Datum - North American Datum of 1983 (NAD 83), National Adjustment of 2011 (NA2011) (epoch 2010.00)
    - Vertical Datum – North American Vertical Datum of 1988 (NAVD 88); using the latest NGS-approved geoid (GEOID12B) for converting ellipsoid heights to orthometric elevations
    - Units – **Meters**

❖ LiDAR post-processing
- Laser
- Inertial Measurement Unit (IMU)
- Airborne GPS (AGPS)
  - aka Global Navigation Satellite System (GNSS)

- LiDAR calibration / boresight
- LiDAR classification (ASPRS LAS 1.4, point record format 6)
  - Minimum standards as outlined in TM11-B4
  - SNWA
    - Class 1 = Unclassified
    - Class 2 = Bare-earth ground
    - Class 7 = Low point (noise)
    - Class 9 = Water
    - Class 10 = Ignored ground (near a breakline)
    - Class 17 = Bridge decks
    - Class 18 = High noise
  - DCP
    - Class 1 = Unclassified
    - Class 2 = Bare-earth ground
    - Class 3 = Low vegetation (small shrubs 0.3-0.6m)
    - Class 4 = Medium vegetation (medium shrubs 0.6-1.5m)
    - Class 5 = High vegetation (tamarisk/mesquite 1.5-5.0m)
    - Class 64 = Excessive vegetation (cottonwoods/willow/mesquite >5.0m)
    - Class 7 = Low point (noise)
    - Class 9 = Water
    - Class 10 = Ignored ground (near a breakline)
    - Class 17 = Bridge decks
    - Class 18 = High noise
- Hydro-flattening breakline collection
  - Minimum standards as outlined in TM11-B4
  - Waterbodies
    - ≥2 acres
  - Inland Streams and Rivers
    - ≥100’ nominal width
  - Islands
    - ≥1 acre
    - Permanent
  - All hydro-flattening breaklines requires monotonicity
- NO planimetric feature collection
- NO contour interpolation
- QA/QC
  - Per GSS QMS
- Deliverables
  - Minimum standards as outlined in TM11-B4
  - SNWA
    - Raw LiDAR point cloud
      - Fully compliant ASPRS LAS 1.4, point record format 6
      - Calibrated
      - By swath
      - Intensity values normalized (rescaled) to 16-bit
      - FGDC-compliant metadata
    - Classified LiDAR point cloud

- Fully compliant ASPRS LAS 1.4, point record format 6
- By tile
- Intensity values normalized (rescaled) to 16-bit
- FGDC-compliant metadata

▪ Hydro-flattened breaklines
- Project-wide Esri feature class(es) or shapefile(s) for insertion into file geodatabase
- FGDC-compliant metadata

▪ Bare-earth DEM
- Two-foot (2') cell size 32-bit floating point raster in GeoTIFF format
- Bare-earth (hydro-flattened)
  - ♦ Culverts will not be removed from the DEMs
  - ♦ Bridges will be removed from the DEMs
- By tile
- FGDC-compliant metadata

▪ FGDC-compliant metadata (project level)

▪ Miscellaneous Esri shapefiles
- Boundary(ies)
- Tiles
- Control
- LiDAR checkpoints (NVA/VVA)
- Raw LiDAR swaths

➢ DCP

▪ Classified LiDAR point cloud
- Fully compliant ASPRS LAS 1.4, point record format 6
- By tile
- Intensity values normalized (rescaled) to 16-bit
- FGDC-compliant metadata

▪ Hydro-flattened breaklines
- Project-wide (AOI-wide) Esri feature class(es) or shapefile(s) for insertion into file geodatabase
- FGDC-compliant metadata

▪ Bare-earth DEM
- One-meter (1m) cell size 32-bit floating point raster in GeoTIFF format
- Bare-earth (hydro-flattened)
  - ♦ Culverts will not be removed from the DEMs
  - ♦ Bridges will be removed from the DEMs
- By tile and AOI (mosaic)
- FGDC-compliant metadata

▪ Hillshades
- 1m cell size in GeoTIFF format
- By tile and AOI
- FGDC-compliant metadata

▪ Vegetation classified images
- 1m cell size in GeoTIFF format
- By tile and AOI

        - FGDC-compliant metadata
    - Intensity Images
        - 1m cell size 8-bit, 256 color gray scale in GeoTIFF format
        - By tile and AOI
        - FGDC-compliant metadata
    - FGDC-compliant metadata (project level)
    - Miscellaneous Esri shapefiles
        - Boundary(ies)
        - Tiles
        - Control
        - LiDAR checkpoints (NVA/VVA)
        - Raw LiDAR swaths
- Detailed LiDAR Mapping / Project Report

- Lump Sum Fee
    - **$199,784.50**
        - SNWA
            - $116,259.87
        - DCP
            - $ 83,524.63

Should you have any questions or comments regarding the content of the SOW, please feel free to contact me at 303-353-3903. I can also be e-mailed at doug.jacoby@merrick.com. Thank you for the opportunity to support SNWA and DCP.

Sincerely,

Merrick & Company

Doug Jacoby, CMS, GISP
Geomatics – GSS Practice Lead

cc: Judy Brandt, Senior Remote Sensing Analyst, SNWA
Lee Bice, Senior GIS Analyst, DCP