4. Specifications

4.1 PURPOSE AND INTRODUCTION

The State of Kansas, on behalf of the Kansas Department of Agriculture and Kansas Data Access and Support Center, has contracted with Atlantic for professional services related to the development of Light Detection and Ranging (LiDAR) data between November 2014 and March 2015. Additional partners include the USDA Natural Resource Conservation Service, the U.S. Geological Survey, the Kansas GIS Policy Board, the Kansas Department of Transportation and the Kansas Water Office. These LiDAR elevation data will be used for conservation planning, design, research, floodplain mapping, wetlands identification, dam safety assessments, hydrologic modeling, and subsidence monitoring.

4.2 PROJECT AREA

The area represents Republic, Cloud, Washington and Clay Counties and buffers around each for a total of 3,330 square miles.

4.2.1 Defined Project Area

The area represents Republic, Cloud, Washington and Clay Counties and buffers around each for a total of 3,330 square miles.

4.2.2 Collection Area

The defined project area (DPA) shall be buffered by 100 meters to create a buffered project area (BPA). Data collection is required for the full extent of the BPA.

In order for all products to be consistent to the edge of the DPA, all products shall be generated to the full extent of the BPA. Data and products in the buffer will not be tested for any quality requirement. Control points may be located in the buffer; check points shall not be located in the buffer area.

4.3 GENERAL REQUIREMENTS

Project will follow USGS Lidar Base Specifications, Version1.2 unless otherwise noted.

4.3.1 Project Initiation Plan

A detailed project plan must be submitted for approval within 7 days of receiving notice to proceed and prior to any data acquisition activities. The plan shall consist of the following:

A. Schedule (data acquisition, data processing, data delivery).
B. Project personnel with contact information of the project and field operation manager(s) C. Proposed flight lines in GIS and graphic format
D. Base station locations in GIS and graphic format as well as supporting NGS control information
E. Proposed baseline lengths for aerial collection
F. Calibration testing methodology(s)
G. LiDAR collection parameters (flying height, Scan FOV full angle, pulse rate, scanner frequency, side-lap percentage, point density etc.)
H. Proposed acquisition windows including maximum PDOP values
I. Description of internal verification quality control processes;
    1) Data validation
    2) Pre-processing and accuracy check
    3) Processing quality control
    4) Product delivery quality control

4.3.2 LiDAR Data Acquisition Parameters

LiDAR data shall be collected using an approved fully calibrated system capable of collecting multiple echoes per pulse with a minimum of a first, last, and one intermediate return. The system must also be able to collect the intensity (LiDAR pulse signal strength) for each return signal.

4.3.3 Sensor Calibration

Full system calibration and routine maintenance should be up-to-date to ensure full functionality of the LiDAR system to meet and exceed project accuracies and requirements. Full calibration reports should be available if requested. Bore site calibrations shall be performed at the beginning and end of the project and as needed throughout the data collection period. Alternative testing methodologies may be used upon review and acceptance by KDA prior to any data acquisition activities.

4.3.4 Acquisition Window

LiDAR acquisition shall occur during leaf-off conditions but prior to March 31, 2017. Prior KDA consent will be required before the initial project data collection.

4.3.5 Ground Control

All survey conducted under this project shall be referenced to National Geodetic Survey (NGS) control monuments in the National Spatial Reference System (NSRS) using appropriate horizontal and vertical control. Ideally checkpoint surveys should utilize or tie into the same base station control monuments used for the aerial acquisition to eliminate the possibility of discrepancies between different control stations. Base station locations should be the "best" horizontal (second order or better) and vertical (second order or better) available and have a stability of "C" or better. In the event that no suitable base station monuments exist, new primary ground control will be required and shall conform to the Standards and Specifications for Geodetic Control Networks (1984), Federal Geodetic Control Committee (FGCC).

Primary control monuments established with GPS shall meet or exceed NOS NGS-58 "Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm)" using the appropriate latest geoid model and should be monumented to maintain stability. Ground control stations are expected to have a local network accuracy at the 95% confidence level of 2 cm horizontally and vertically. Any control points set shall be of a permanent or semi-permanent nature such as copperweld or re-bar type rods referenced for recovery by others in the future and for performing quality control checks. Survey check points do not require monumentation.

The survey points for the accuracy assessment must have an identification number for each point in the ESRI shape file and in the RMSE error report. The land cover type for each point must be identified in the metadata file. Additional supporting documentation may include processing reports, minimally and constrained 3-D least squares adjustment, pictures of the station, etc.

For aerial acquisition a minimum of two base stations capable of collecting dual frequency data at 1 Hz or greater is required. Baseline lengths to achieve the desired accuracy should not exceed 25 miles. For quality control, forward and reverse processing of the trajectories should yield similar results and these comparisons should be made available if requested. Additionally other quality statistics from the airborneGPS/IMU processing such as DOP values, resolved ambiguity reports, accelerometer and gyro drift and scale factors etc. should be made available if requested.

Alternate methods for GPS/GNSS post processing may be used but must be approved by the agency prior to implementation. Independent verification of vertical and horizontal accuracy is expected using CORS or a single base station will still be expected.

4.4 LiDAR COLLECTION

4.4.1 Multiple Discrete Return, capable of at least 3 returns per pulse

4.4.2 Intensity values are required for each return. The values are to be recorded in the. las files normalized to 16-bit as required by the LAS specification.

4.4.3 Aggregate Nominal Pulse Spacing (ANPS) of no greater than 0.71 meter, dependent on the local terrain and landcover conditions. Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically —90%) of each swath. Average along-track and cross-track point spacings should be comparable.

4.4.4 Data Voids [areas => $(4*NPS)^2$, measured using 1st returns only] within a single swath are not acceptable, except:

a) where caused by water bodies

b) where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing.

c) where appropriately filled-in by another swath

4.4.6 The spatial distribution of geometrically usable points is expected to be uniform and free from clustering. In order to ensure uniform densities throughout the data set:

a) A regular grid, with cell size equal to the design NPS*2 will be laid over the data.

b) At least 90% of the cells in the grid shall contain at least two LiDAR point.

c) Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically —95%) of each swath.

d) Acceptable data voids identified previously in this specification are excluded.

e) Aggregate nominal pulse density (ANPD) of the LiDAR shall be equal to or greater than 2.0 pulses per square meter (ppsm)

4.4.7 Positional Accuracy Validation will require the absolute and relative vertical accuracy to be verified. A detailed report of the validation processes shall be delivered.

a) Relative Vertical Accuracy refers to the internal geometric quality of a lidar dataset, without regard to surveyed ground control. Two primary factors will be assessed:

- Smooth Surface repeatability (intraswath) is a measure of variations on a surface expected to be flat and without variation. Single-swath data will be assessed using only single returns in nonvegetated areas. The maximum acceptable variations within sample areas are <= 6 cm.

- Overlap consistency is a measure of geometric alignment of two overlapping swaths. Multiple locations within overlap in nonvegetated areas of only single returns will be assessed. Differences in swath overlap will not exceed a maximum of 16 cm or <=8 cm RMSDz.

b) Check Points. The Positional Accuracy Standards for Digital Geospatial Data (American society for Photogrammetry and Remote Sensing, 2014) ties the required number of check points for vertical accuracy assessment to the areal extent of the project.

- Nonvegetated Vertical Accuracy (NVA) check points shall be surveyed in clear, open areas, devoid of vegetation and other vertical artifacts. Ground that has been plowed or otherwise disturbed is not acceptable. The same check points may be used for NVA assessment of the point cloud and DEM.

- Vegetated Vertical Accuracy check points shall be surveyed in vegetated areas (typically characterized by multiple return data).

- Quantity of check points shall meet ASPRS Positional Accuracy Standards for Digital Geospatial Data recommendations.

- Distribution of checkpoints shall meet ASPRS Positional Accuracy Standards for Digital Geospatial Data recommendations.

- Check points shall not be incorporated in contractor's vertical solution.

c) Absolute Vertical Accuracy. Three absolute accuracy values shall be assessed and reported: NVA for the point cloud, NVA for the DEM, and VVA for the DEM.

- The unclassified point cloud shall meet the required NVA before further classification and processing. The NVA for the point cloud is assessed by comparing check points survey in clear, open, nonvegetated areas to a triangulated irregular network (TIN) constructed from single return lidar points in those areas.

- NVA absolute vertical accuracy for lidar-swath data shall meet QL2, <=10.0 cm RMSEz, 95-percent confidence level <=19.6 cm.

- NVA absolute vertical accuracy for DEMs shall meet QL2, <=10.0 cm RMSEz, 95- percent confidence level <=19.6 cm.

- VVA absolute vertical accuracy for DEM shall meet QL2, 95th percentile <=29.4 cm.

d) Reporting on the assessment of the vertical accuracy shall include the following at a minimum:

a. A description of the process used to test the points

b. A graphic depicting the spatial distribution of the ground survey checkpoints

c. An analysis of checkpoints that have errors exceeding the 95th percentile in VVA calculations

d. Descriptive statistics and RMSEz in the NVA calculations e. Provide shapefile or geodatabase file of all checkpoints

4.4.8 Collection Area: Defined Project Area per shapefile plus 100 meter buffer.

4.4.9 Collection Conditions:

a) Atmospheric: Cloud and fog-free between the aircraft and ground

b) Ground:

i. Snow free. Very light, undrifted snow may be acceptable in special cases, with prior approval.

ii. No unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation.

c) Vegetation: Leaf-off is preferred.

4.5 DATA PROCESSING and HANDLING

4.5.1 All processing should be carried out with the understanding that all point deliverables are required to be in fully compliant LAS format, v1.4.

4.5.2 GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse. Adjusted GPS Time is defined to be Standard (or satellite) GPS time minus 1*109. See the LAS Specification for more detail.

4.5.3 Horizontal datum shall be referenced to the North American Datum of 1983/HARN adjustment. Vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88). The most recent NGS-approved Geoid model (currently Geoid12A) shall be used to perform conversions from ellipsoidal heights to orthometric heights.

4.5.4 The Coordinate Reference System is UTM Zone 14 & 15 North for the tiling scheme across the entire project area. All units will be to a centimeter resolution.

4.5.5 Each swath shall be assigned a unique File Source ID. The Point Source ID field for each point within each LAS swath file shall be set equal to the File Source ID prior to any processing of the data. See the LAS Specification.

4.5.6 Point Families (multiple return "children" of a single "parent" pulse) shall be maintained intact through all processing prior to tiling. Multiple returns from a given pulse shall be stored in sequential (collected) order.

4.5.7 All collected swaths are to be delivered as part of the Raw Point Cloud. This includes calibration swaths and cross-ties. All collected points are to be delivered. No points are to be deleted from the swath LAS files. This in no way requires or implies that calibration swath data are to be included in product generation. Excepted from this are extraneous data outside of the buffered project area (aircraft turns, transit between the collection area and airport, transit between fill-in areas, etc.). These points may be permanently removed.

4.5.8 Use of LAS Withheld Flag. Outliers, blunders, noise points, geometrically unreliable points near the extreme edge of the swath, and other points deemed unusable are to be identified using the "Withheld" flag, as defined in the LAS specification.

a) This applies primarily to points which are identified during pre-processing or through automated post-processing routines as geometrically unusable.

b) "Noise points" subsequently identified during manual Classification and Quality Assurance/Quality Control (QA/QC) may be assigned the standard LAS classification values for Low Noise (Class=7) and High Noise (Class 18).

4.5.9 Use of LAS Overlap Flag. Overage points shall be identified using LAS overlap flag in all point cloud deliverables. The legacy (LAS v1.3 and earlier) ASPRS/LAS "Overlap" classification (Class=12) shall not be used. Additionally, ALL overlap points not identified as "Withheld" are to be classified in a normal way. However, overlap points should not be included in the DEM generation as that will result in an inconsistent surface.

4.5.10 Positional Accuracy Validation: The absolute and relative accuracy of the data, both horizontal and vertical, and relative to known control, shall be verified prior to classification and subsequent product development. This validation is obviously limited to the Nonvegetated Vertical Accuracy, measured in clear, open areas. A detailed report of this validation is a required deliverable.

4.5.11 Classification Accuracy: It is expected that due diligence in the classification process will produce data that meets the following test:

i. Within any 1km x 1km area, no more than 1% of non-withheld points will have demonstrable errors in classification value.

ii. No non-withheld points will remain in Class 0.

iii. Points remaining in Class 1 that should be classified in any other required class are subject to these accuracy requirements and will be counted towards the percentage thresholds.

4.5.12 Classification Consistency: Point classification is to be consistent across the entire project. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, lifts, or other non-natural divisions will be cause for rejection of the entire deliverable.

4.5.13 Tiles:

a) Tiled deliverables shall conform to the tiling scheme, without added overlap.

b) Tiled deliverables shall edge-match seamlessly and without gaps in both the horizontal and vertical.

c) Tile Naming Convention: Tiles will be named based on southwest corner of the 5,000 m x 5,000 m US National Grid square.
Example: 14S PJ 2590
Where: 3 digit Grid Zone Designation, i.e. 14S
100,000-m Square Identification, i.e. PJ
2 digit West corner of 5,000 m grid, i.e. 25
2 digit South corner of the 5,000 m grid, i.e. 90

4.6 HYDRO-FLATTENING REQUIREMENTS

Hydro-flattening pertains only to the creation of derived DEMs. No manipulation of or changes to originally computed LiDAR point elevations are to be made. Breaklines may be used to help classify the point data. DEMs should represent water bodies in a cartographically and aesthetically pleasing manner. It is not the goal to map water surface elevations. The requirements for hydro-flattening are listed below. These requirements also define the minimum features for which breaklines must be collected and delivered.

4.6.1 Inland Ponds and Lakes:

a) —3/4-acre or greater surface area (-3,000 sq meters or greater) at the time of collection.

b) Flat and level water bodies (single elevation for every bank vertex defining a given water body).

c) The entire water surface edge must be the shoreline where the water meets the immediately surrounding terrain. The presence of floating or digging water bodies will be cause for rejection of the deliverable.

d) Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations drop when moving downstream, should be treated as rivers.

4.6.2 Inland Streams and Rivers:

a) 50' **nominal** width: This should not unnecessarily break a stream or river into multiple segments. At times it may squeeze slightly below 50' for short segments. Data producers should use their best professional judgment.

b) Flat and level bank-to-bank (perpendicular to the apparent flow centerline); gradient to follow the immediately surrounding terrain.

c) The entire water surface edge must be at the shoreline location where the water meets the immediately surrounding terrain.

d) Stream channels should break at road crossings (culvert locations). The roadway over a culvert should be continuous. A culvert, regardless of size, is defined as having earth between the road surface and the stop of the structure.

e) Bridges are required to be removed from DEM. Streams and rivers should be continuous at bridge locations. Bridges are defined as having an elevated deck structure that does not rest on the earth.

f) When the identification of a feature as a bridge or culvert cannot be made reliably, the feature should be regarded as a culvert.

4.6.3 Non-Tidal Boundary Waters:

a) Represented only as an edge or edges within the project area; collection does not include the opposing shore.

b) The entire water surface edge must be at or below the immediately surrounding terrain.

c) The elevation along the edge or edges should behave consistently throughout the project. May be a single elevation (i.e., lake) or gradient (i.e., river), as appropriate.

4.6.4 Islands

a) Permanent islands 1 acre or large shall be delineated within all water bodies.

4.6.5 Additional general guidelines for breaklines must be adhered to:

a) Bare-earth LiDAR points that are in close proximity breaklines should be excluded from the DEM generation process. This is analogous to the removal of masspoints for the same reason in a traditional photogrammetrically compiled DTM.

The proximity threshold for reclassification as "Ignored Ground" is at the discretion of the data producer, but in general should not exceed the ANPS.

b) These points are to be retained in the delivered LiDAR point dataset and shall be reclassified as "Ignored Ground" (class value = 10) so that they may be subsequently identified.

c) Delivered data must be sufficient for the STATE OF KANSAS to effectively recreate the delivered DEMs using the LiDAR points and breaklines without significant further editing.

4.7 DELIVERABLES

The State of Kansas shall have unrestricted rights to all delivered data and reports, which will be placed in the public domain. This specification places no restrictions on the data provider's rights to resell data or derivative products as they see fit.

4.7.1 Products

A. Metadata

1) Collection Report detailing mission planning and flight logs.

2) Survey Report detailing the collection of all ground control, including the following:

- Control points used to calibrate and process the lidar and derivative data.
- Check points used to validate the lidar point data or any derivative product.

3) Processing Report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening

4) QA/QC Reports (detailing the analysis, accuracy assessment and validation of:

- Point data (absolute vertical accuracy [NVA], relative vertical accuracy).
- Bare-earth surface (absolute vertical accuracy [NVA and VVA]).)
- Other optional deliverables as appropriate

5) Geo-referenced, digital spatial representation of the precise extents of each delivered dataset.

- The extents of the actual LiDAR source or derived product data, exclusive of Triangular Irregular Network (TIN) artifacts or raster void areas.
- A union of tile boundaries or minimum bounding rectangle is not acceptable.
- ESRI Polygon shapefile or geodatabase is preferred.

6) Product metadata (FGDC compliant, XML format metadata).

a) Overall Project describing the project boundary, the intent of the project, the types of data collected as part of the project, the various deliverables for the project, and other project-wide information.

b) Each Lift describing the extents of the lift, the swaths included in the lift, locations of GPS base stations and control for the lift, preprocessing and calibration details for the lift, adjustments and fitting processes applied to the lift in relation to other lifts, and other lift-specific information.

c) Each tiled deliverable product group:

- Classified point data
- Bare-earth DEMs
- Breaklines
- Intensity Images

d) Individual tiles for all products

7) FGDC compliant metadata must pass the USGS metadata parser ("mp") with no errors or warnings.

B. Raw Point Cloud

1) All collected points, fully calibrated, georeferenced, and adjusted to ground, organized and delivered in their original swaths, one file per swath, one swath per file. If production processing required segmentation of the swath files, follow instructions in USGS Lidar Base Specification, Version 1.2.

2) Fully compliant LAS Specification version 1.4, Point Record Format 6, 7, 8, 9, or 10.

3) Correct and properly formatted georeferenced information as Open Geospatial Consortium (OGC) well known text (WKT) in all LAS file headers.

4) No classifications are required, however, proper use of Withheld and Overlap flags is required.

5) GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse.

6) Intensity values, normalized to 16-bit as required by the LAS specification.

7) Report of the assessed relative vertical accuracy of the point cloud (smooth surface repeatability and overlap consistency). See Positional Accuracy Validation section requirements.

8) Report of the assessed absolute vertical accuracy (NVA only) of the unclassified lidar point data. See Positional Accuracy Validation section requirements.

C. Classified Point Cloud

1) All project swaths, returns, and collected points, fully calibrated, adjusted to ground, and classified, by tiles.

2) Fully compliant LAS v1.4, Point Data Record Format 6, 7, 8, 9, or 10.

3) Correct and properly formatted georeferenced information as OGC WKT included in all LAS file headers.

4) GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse.

5) Intensity values, normalized to 16-bit as required by the LAS specification.

6) Tiled delivery, without overlap, using the project tiling scheme.

7) Classification Scheme:

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Low Noise
9	Water
10	Ignored Ground (Breakline Proximity)
17	Bridges
18	High Noise

Note: Class 10, Ignored Ground, is for points previously classified as bare-earth but whose proximity to a subsequently added breakline requires that it be excluded during Digital Elevation Model (DEM) generation.

D. Bare Earth Surface (Raster-based DEM derived from bare-earth points of the filtered bare-earth data)

1) Bare-earth DEM, generated to the limits of the BPA.

2) Horizontal DEM grid spacing of 1 meter.

3) Delivery in 32-bit floating point raster format ERDAS .IMG format.

4) Georeference information shall be included in each raster file

5) Tiled delivery, without overlap

6) DEM tiles will show no edge artifacts or mismatch. A quilted appearance in the overall project DEM surface, whether caused by differences in processing quality or character between tiles, swaths, lifts, or other non-natural divisions, will be cause for rejection of the entire DEM deliverable.

7) Void areas (i.e., areas outside the BPA but within the tiling scheme) shall be coded using a unique "NODATA" value. This value shall be identified in the appropriate location within the file header.

8) QA/QC analysis materials for the absolute vertical accuracy assessment.

9) A report on the assessed absolute vertical accuracy (NVA and VVA) of the bare-earth surface in accordance with the guidelines set forth in the "Positional Accuracy Standards for Digital Geospatial Data" (ASPRS, 2014).

10) Depressions (sinks), natural or man-made, are **not** to be filled.

11) Hydro Flattening of Water Bodies (ponds and lakes), wide streams and rivers ("double-line"), and other non-tidal water bodies as defined in Hydro-Flattened Section. Hydro-flattening shall be applied to all water impoundments, natural or man-made, that are larger than —3/4 acre in area (equivalent to 3,000 square meters in area), to all streams that are nominally wider than 50', and to all non-tidal boundary waters bordering the project area regardless of size.

12) Bridges (defined as having an elevated deck structure that does not rest on earth) shall be removed. Road or other travel ways over culverts remain intact in the surface.

13) Bare-Earth DEM shall support the development of **1** foot contours.

E. First Return (Raster DEM)

1) First Return DEM, generated to the limits of the BPA.

2) Horizontal DEM grid spacing of 1 meter.

3) Delivery in 32-bit floating point raster format ERDAS .IMG format.

4) Georeference information shall be included in each raster file

5) iled delivery, without overlap

F. Hydro Polygon Breaklines

1) Breaklines developed to the limit of the BPA.

2) All breaklines representing hydro-flattened features shall be delivered as a 3-D features (Poly lineZ and PolygonZ) in geodatabase format.

3) Each feature class will include properly formatted and accurate georeference information stored in that format's in the standard file system location. Each shapefile shall include a correct and properly formatted .prj file.

4) Breaklines must use the same coordinate reference system (horizontal and vertical) and units as the LiDAR point delivery.

5) Breakline delivery will be as a continuous layer for each delivery area.

6) All water bodies > % acres and streams > 50 feet wide will be delineated.

7) Breakline delivery shall be a single layer production block (not by tiles).

G. Intensity Images

1) Intensity values will be reported for the first return

2) 256 grey scale; 8 bit; no compression

3) ERDAS AMC format

4.7.2 Media and Data Ownership

All LiDAR data and supplemental products will be delivered on USB external hard drives and will become the property of the State of Kansas. All media and data collected under this contract shall be the sole

property and can be freely distributed by the State of Kansas. No restrictions shall be placed on the data by the LiDAR provider.