Lidar Standards

Chatham County, Georgia

Jason Lee, Noel Perkins and Vincent Grevemberg

CHATHAM COUNTY - SAVANNAH METROPOLITAN PLANNING COMMISSION
mpc
GEORGIA 1955

SAGIS
Savannah Area Geographic Information System

SAGIS Lidar Standards

Table of Contents

1 Introduction

This document presents the standards by which lidar is collected, processed and delivered to Savannah Area GIS (SAGIS) and or partners of SAGIS. Specifications include all details SAGIS deems relevant to create a product of consistent appearance and accuracy for the multiple uses required by the citizens of Chatham County and Savannah.

1.1 Objective

These specifications are not written as a static document, but as needs and GIS continue to evolve so will this document. SAGIS anticipates this, and will monitor and improve on these specifications as needed.
As a benchmark, all lidar data must always meet or exceed the guidelines set forth in FEMA's Guidelines and Specifications for Flood Hazard Mapping (http://www.fema.gov/pdf/fhm/frm_gsaa.pdf).
In this document, SAGIS frequently refers to the Florida Division of Emergency Management's lidar standards contained in 'Baseline Specifications for Orthophotography and Lidar V 1.2' (http://floridadisaster.org/gis/specifications/Documents/BaselineSpecifications_1.2.pdf). After much research and consideration, SAGIS has concluded that the Florida Disaster standards are comprehensive and thorough, and the SAGIS Lidar Standards are intended to be an adaptation of those. In this document, primary portions of the 'Baseline Specifications' are restated verbatim, changed as we deemed necessary to fit SAGIS requirements or specifications, to state our specific goals or to exclude unnecessary sections. Direct references are notated as such (Florida Disaster Specifications; FDS). It is important to note that the Florida Disaster standards were developed, after much trial and error, in areas of mostly flat terrain common to the lower Atlantic Coastal Plain, where Savannah/Chatham County is situated. SAGIS would also like to sincerely thank both Steve Dicks and Al Karlin from the Southwest Florida Water Management District for their advice and input in drafting this document.

2 Data Description

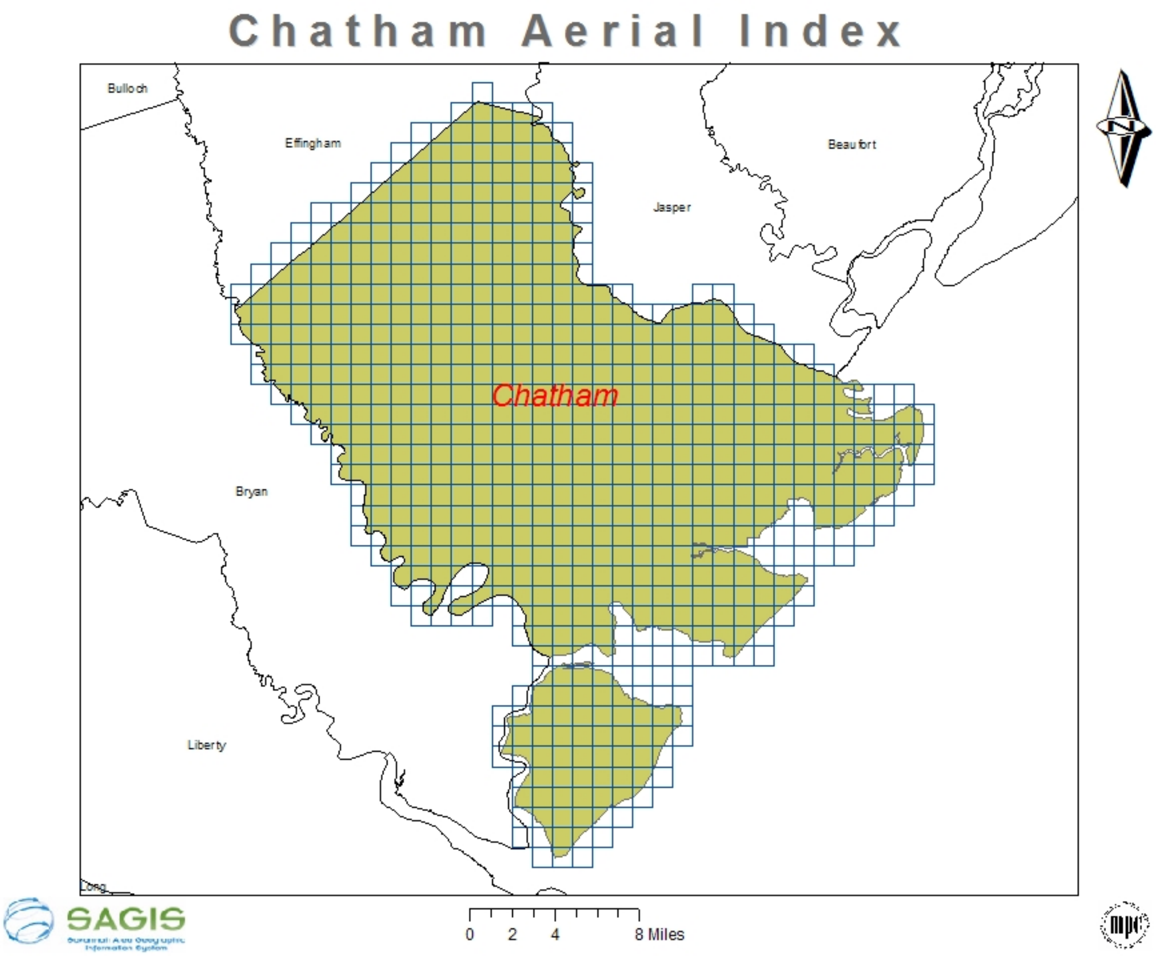
For the purposes of this document, SAGIS defines Light Detection and Ranging (LiDAR; lidar) technology as a remotely sensed product and process that measures the time delay between a light pulse transmission and reception. It is represented in its raw data format as a series of x,y and z points where x and y are longitude and latitude and z is elevation. Highly accurate Digital Elevation Models, Digital Terrain Models, Digital Surface Models and Contour Lines can be created from the raw data. There are multiple applications for these products, most importantly floodplain mapping, flood forecasting and other hydrologic modeling- all essential information for coastal Chatham County.

3 Spatial and Temporal Environments

3.1 Spatial Extent and Tiling

SAGIS requires that its orthoimagery and lidar be tiled according to the Chatham County Aerial Index (Figure 1). This Index will be provided to the contractor by SAGIS. The Areal Extent of Lidar shall also be based on this layer, unless otherwise specified. Note that the entire land area of Chatham County is included, and that certain areas in the eastern portion of the county may change significantly due to beach/dune migration and other geophysical processes. It is required that ALL of these areas be captured. The Metadata should list all date(s) and time(s) of acquisition in conjunction with each tile identifier. The polygonal Index should also be amended to reflect any multiple images in individual tiles (footprints) and both a date field named DATE and a time field named TIME should be added.

Figure 1.



3.2 Acquisition times

Leaf off conditions will be required to minimize obstruction by tree canopy and other vegetation unless otherwise stated. 'Leaf off' will be defined as that seasonal time period when deciduous trees have lost their leaves, typically December, January and February for coastal Georgia. However, since this time frame can vary year to year, acquisition times require pre-approval by SAGIS, and will be rejected if optimal conditions are not met.
Low tide acquisition will be considered optimal and so is an important feature of this project. Low tide will be defined as the lower third of the tide cycle, and all tidal areas must be flown within that four hour window (two hours before low tide, and two hours after).

Sensor

4.1 Sensor Equipment

All Lidar data will be collected using a SAGIS approved sensor with a maximum field of view (FOV) of 40^{0} (20^{0} off nadir).

4.2 Sensor Calibration (Florida Disaster Specifications; FDS)

Routine sensor calibration and maintenance are required to ensure proper function of the lidar system. Any requests by funding agencies to submit evidence that the sensor system was calibrated before the project began to identify and correct systematic errors must be met. Bore-sight calibration should be performed at least twice during each project, at the beginning and the end of a project. Additional bore-sight calibrations should be done as necessary to ensure accuracy.

5 Lidar Parameters and Specifications

5.1 Post Spacing

The lidar cloud will be collected at a **maximum** post spacing of either **<u>0.7 or 1 meter</u>** where possible. SAGIS understands that in obscured areas this standard may not be met.

The proposer should provide the following information regarding post spacing for both the .7m and 1m options:

- maximum along track post spacing (within useable data)
- maximum cross track post spacing (within useable data)

- FOV
- altitude
- airspeed
- sidelap

5.2 Accuracy

Horizontal accuracy shall be tested to meet or exceed a 3.8-foot horizontal accuracy at the 95% confidence level using RMSE(r) x 1.7308 as defined by the FGDC Geospatial Positioning Accuracy Standards, Part 3: NSSDA. Methodology, results, and findings of horizontal accuracy testing shall be disclosed in the Survey Report. SAGIS will require that GeoCue lidar FMAS (Feature Matching and Adjustment System) CuePac module (or a similar, SAGIS approved methodology) be used to compute horizontal accuracy metrics.

The vertical accuracy testing for lidar data over well-defined surfaces shall meet or exceed requirements as set forth in the Federal Geographic Data Committee's (FGDC) Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy (NSSDA). Vertical accuracies at the 95% confidence level for flat terrain are required, assuming all systematic errors have been eliminated to the greatest extent possible and the errors are normally distributed. Fundamental vertical accuracy shall be tested to meet a **7.2" (18cm)** fundamental accuracy at the 95% confidence level using RMSE(z) x 1.9600 (as defined by the "ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data"). This guideline implements the NSSDA for testing of lidar data. The Vertical Accuracy Assessment section (9) details this further.

5.3 Lidar Mapping Survey Control (FDS)

The lidar ground control must be adequate to support the accuracy specifications identified for particular projects. A survey report that documents and certifies the procedures and accuracies of the horizontal and vertical control, aircraft positioning systems, and system calibration procedures used in the Lidar mapping project shall be created. Baseline distances for GPS ground control shall not exceed 20 miles.

The horizontal and vertical control shall be based on direct ties to National Geodetic Survey (NGS) control stations, National Spatial Reference System (NSRS). All geodetic control surveys, both horizontal and vertical, shall conform to the Standards and Specifications for Geodetic Control Networks (1984), Federal Geodetic Control Committee (FGCC). The horizontal control shall reference the North American Datum of 1983/ High Accuracy Reference Network (NAD83/HARN). Procedures used to establish horizontal photogrammetric ground control using GPS measurements shall meet or exceed Second Order Horizontal Control as set forth by the FGCC, Geometric Geodetic Accuracy Standards and Specifications for using GPS Relative Positioning Techniques, Version 5.0, May 1988. The vertical control shall reference the North American Vertical Datum of 1988 (NAVD88) using Geoid03 to perform conversions from ellipsoidal heights to orthometric heights. Procedures used to establish vertical control shall meet or exceed Third Order Vertical Control Accuracy Standards and Specifications. Procedures for

GPS-Derived elevation differences shall meet or exceed Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 centimeters and 5 centimeters), NGS-58, November 1997, and/or Guidelines for Establishing GPS-Derived Orthometric Heights (Standards: 2 centimeters and 5 centimeters), NGS-59, October 2005.

All mapping shall be coordinated in planning procedures and methodology used for all control surveys. Mapping shall meet or exceed FEMA Flood Hazard Mapping Program, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, Section A.5 Ground Control, and Section A.6 Ground Surveys.

Note that Savannah/Chatham County has a High Accuracy Continuously Operating Reference Stations (CORS) in place.

SAGIS Specification Table for Lidar

Horizontal Accuracy	3.8-foot horizontal accuracy
RMSE	9 cm/3.6 inch
Post spacing	1 meter OR 0.7 meter
Data Format	LAS 1.1 or newest version
Breaklines	Hydrologically Correct
Primary Projection	State Plane GA East US Foot
Contours	1 foot
DEM	1 meter
Imagery	6 inch

6 Deliverables

6.1 Mass Points (FDS with amendments)

Mass point data shall be delivered in LAS files compatible with the LAS Specification 1.1-lookup format (or latest version at time of acquisition). Required items not specifically noted as required in the LAS 1.1 Specification are defined in the following sections. The mass point data shall not contain ANY holidays in the data as a result of missing mission coverage or system malfunction. The classification code for these files will follow the LAS 1.1 format (or newest version) and will include the following:

- Category 1 = Unclassified
- Category 2 = Ground
- Category 7 = Noise

- Category 9 = Water
- Category 12 = Overlap

• Category 1, 2, 7, and 9 will include lidar points in overlapping flight lines. Category 12 will be used for lidar points, in areas of overlapping flight lines, which have been deliberately deleted and removed from all other classes because of their reduced accuracy possibly due to their off-nadir position.

• Category 1 will be used for all features that do not fit into the Category 2, 7, 9, or 12 including vegetation, buildings, etc.

• Shorelines of water bodies shall be captured as breaklines and lidar measurements inside of water bodies will be classified as water in the LAS deliverable.

• A complete lidar cloud shall be delivered where the bare earth classification (Category 2) is free of artifacts not representing the earth's surface (cell towers, birds, etc.). These artifacts shall be classified as Category 7 – Noise as defined above.

• Only the bare earth classification (Category 2) shall be loaded into the MASSPOINT feature class. Details of the bare earth cleaning process MUST be provided; both manual and automated procedures must be employed. 97% removal of all ground artifacts, vegetation, anomalies or other errors MUST be met. The simultaneous imagery must be used in the vegetation removal process, and details of how it is employed must be supplied in proposal. The imagery must be incorporated into all quality control procedures.

6.2 Breaklines (FDS with amendments)

Breaklines shall be delineated to ensure the Digital Terrain Model (DTM) is hydrologically correct. *Hydrologically enforced elevation data* is defined as "Hydroenforced TIN's, DEM's, or contours ensure that <u>top surfaces of bridges and culverts are cut by stream breaklines</u> so that computer models will accurately represent drainage flow" in FEMA's Appendix A A.4.10. Proposed breakline compilation techniques shall be defined and approved before data collection. Where possible, the lidar takes precedence over the photos (which must be flown simultaneously with lidar at no more than 6" resolution) for the existence of a feature and horizontal placement of a breaklines. The simultaneous imagery must be used for reference in breakline production, and details of how that process must be supplied in the proposal. The imagery must be incorporated into all breakline quality control procedures. It is important to note that the simultaneous imagery does NOT have to meet the standards to produce breaklines at the .6 foot level **IF** (and only if) the vendor is using lidargrammetry, but must at least be used as a reference. Specific details in how the imagery is incorporated into the process must be given. The following guidelines and attributed feature classes will be used when developing breaklines:

- Breaklines will be delivered in ArcGIS geodatabase format. Separate feature classes must be delivered for each breakline feature type defined below. Each feature class contains a DATESTAMP field which shall be populated with the date the feature was added to the geodatabase.

- Feature classes must be contained within a feature dataset with proper horizontal and vertical spatial references defined. Feature classes must be Z-enabled where defined as three-dimensional breakline features below. Those features captured as two-dimensional breaklines must have a floating point ELEVATION attribute.

- Breaklines will be captured for hydrologically significant features as appropriate to support the development of a terrain surface meeting a 0.6-foot fundamental vertical accuracy at the 95% confidence level. Fundamental vertical accuracy is computed in open terrain using the formula RMSE(z) x 1.9600 (as defined by the “ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data.” This guideline implements the National Standard for Spatial Data Accuracy (NSSDA) for testing of Lidar data.

Closed Water Body Features-

Land/water boundaries of constant elevation water bodies (lakes, reservoirs, etc.) will be delivered as closed polygons with a constant elevation that reflects a best estimate of the water elevation at the time the data were captured. Water body features will be captured for features one-half acres in size or greater. Water bodies may be captured as two- or three-dimensional breaklines.
Closed Water Body Features will be compiled as 2D features with a single elevation. An Island within a Closed Water Body Feature will also have a “donut polygon” compiled in addition to an Island polygon.
For docks or piers following (not perpendicular to) the Closed Water Body Features please reference docks or piers under Coastal Shorelines.

Linear Hydrographic Features-

Linear hydrographic features (streams, shorelines, canals, swales, embankments, etc.) will be delivered as breaklines with varying elevations. All stream/river features that are 0.5 miles or greater in length will be captured. Features that are 8 feet or less in width shall be captured as single breakline features. Features that are greater than 8 feet in width shall be captured as double line features. All features will be captured as three-dimensional breaklines. Carry linear hydrographic features through and/or under bridges to the best of the operator’s ability to see. Embankments may be collected as linear hydrographic features if it is a very sharp feature, or can be collected as a Soft Feature.
For docks or piers following (not perpendicular to) the Linear Hydrographic Features please reference docks or piers under section Coastal Shorelines.

Coastal Shorelines-

Coastal shorelines can be captured as two-dimensional linear features with the exception of manmade features with varying heights such as seawalls which must be captured as three-dimensional breaklines. Coastal breaklines will merge seamlessly with linear hydrographic features at the approximate maximum extent of tidal influence. The coastal breakline will delineate the land water interface using the LiDAR data as reference. In flight line boundary areas with tidal variation the coastal shoreline may require some feathering or edge matching to ensure a smooth transition. Orthophotography will not be used to delineate this shoreline.
Docks or piers – These guidelines apply only to docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

Road Features-

Both sides of paved road features, not including bridges and overpasses, shall be captured as edge-of-pavement breaklines. These features will be captured as three-dimensional breaklines.

Soft Features-

In areas where the LiDAR mass points are not sufficient to create a hydrologically correct DTM, soft features such as ridges, valleys, top of banks, etc. shall be captured as soft breaklines of varying elevations. These features will be captured as three-dimensional breaklines. Soft features may also include embankments.

Low Confidence Areas-

Low Confidence Areas are defined as vegetated areas that are considered obscured to the extent that adequate vertical data cannot be clearly determined to accurately define the DTM. These features shall be captured as two-dimensional closed polygon features. These features are for reference information indicating areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation.

Island Features-

The shoreline of islands within water bodies shall be captured as two-dimensional breaklines in coastal and/or tidally influenced areas and as three-dimensional breaklines in non-tidally influenced areas. Island features will be captured for features one-half acre in size or greater. These breaklines will be delivered as closed polygons with constant elevation.
An island within a Closed Water Body Feature will also have a "donut polygon" compiled in addition to an island polygon.

For docks or piers following (not perpendicular to) the Island Features please reference docks or piers under Coastal Shorelines.

Overpasses, Bridges and Culverts-

Overpass and bridge features will be captured as three-dimensional breaklines, capturing the edge of pavement on the bridge (rather than elevation of guard rails or other bridge surfaces).

6.3 Contours

One-foot contours, produced at or above National Map Standards will be created. In bare-earth and urban classes (areas without obstructions), these shall be produced at ASPRS Class 1 (RMSE of 10.2cm) standards. In areas where the ground is moderately obscured (brushy and forested areas), ASPRS Class 2 (RMSE of 20.3cm) will be acceptable.

6.4 Digital Elevation Model

SAGIS requires a 1meter pixel hydrologically correct DEM (processed directly from hydro enforced lidar).

6.5 Raw and Imagery Products

SAGIS requires that all raw products; first return, last return, and intermediate returns be delivered as distinct feature classes and named accordingly. Simultaneously flown 6” imagery must also be acquired and delivered.

6.6 Metadata

Metadata must comply with FGDC Contend Standard for Metadata, which will be drafted for the project as a whole. Processing methodology should be robust in description and each tile and feature class should be considered. Any problems with acquisition or data itself should be detailed here with specific references to problem areas. Summaries of acquisition times with spatial descriptors need to be included. Metadata must be in an ArcGIS 9.x format.
The recommendations in Guidelines for Digital Elevation Data, Version 1.0 (http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf) can serve as a model for the metadata.

6.7 Final Report

The Final Report should contain, in document form, the information found in the Metadata, and also any other information deemed appropriate for use of the Lidar products.

5 Datums

Horizontal datum shall be referenced to the North American Datum of 1983 adjustment. Vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88).

6 Projection

The SAGIS projection is State Plane Georgia East NAD 1983 FIPS 1001. It is based on a Transverse Mercator projection with the following parameters:

False Easting:	656166.666666666510000000
False Northing:	0.000000000000000000
Central Meridian:	-82.166666666666671000
Scale Factor:	0.999900000000000010
Latitude of Origin:	30.000000000000000000
Linear Units	US Foot
Prime Meridian:	Greenwich
Spheroid:	GRS 1980
Semi-minor Axis:	6356752.3141403561
Angular Units:	Degree

7 Accuracy Assessment

SAGIS will have a 3rd party consultant perform both accuracy assessments (horizontal and vertical). Satisfactory accuracy assessment results will be required for completion of the lidar contract.

In the third party horizontal assessment, SAGIS will require that GeoCue lidar FMAS (Feature Matching and Adjustment System) CuePac module (or a similar, SAGIS approved methodology) be used to compute horizontal accuracy metrics. The number of lines digitized for conjugate comparison will be no less than 20; they will represent at least 10 ground miles, and will be determined by SAGIS post-acquisition.

The third party vertical assessment will be based on the following guidelines. An accuracy assessment shall be performed on the post processed data. Five landcover classes will be sampled proportionally to their geographic extent:

- Class 1-bare earth/open terrain
- Class 2- tall weeds, marshes and agriculture
- Class 3-scrub/shrub
- Class 4-forested
- Class 5-urban/built-up.

The minimum number of points per class will be 75 with 500 total points divided among the classes. The proportions should be based on current landcover data, and reported in accordance with the specifications of the FGDC Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy (NSSDA). Checkpoint surveys for vertical accuracy testing shall be made in accordance with FEMA Appendix A. Section A.6.4 Checkpoint Surveys.

Vertical accuracy specifications for data:

In class 1, the $RMSE_z$ ***must*** *be $\leq$ .30 ft ($Accuracy_z \leq$ .60 feet)*
[In class 1, the $RMSE_z$ **must** be $\leq$ 9 cm ($Accuracy_z \leq$ 18 cm)]
[In class 1, the $RMSE_z$ **must** be $\leq$ 3.6 inches ($Accuracy_z \leq$ 7.1 inches)]
In class 2, the $RMSE_z$ ***should*** *be $\leq$ .61 ft ($Accuracy_z \leq$ 1.19 feet)*
In class 3, the $RMSE_z$ should be $\leq$ .61 ft ($Accuracy_z \leq$ 1.19 feet)
In class 4, the $RMSE_z$ should be $\leq$ .61 ft ($Accuracy_z \leq$ 1.19 feet)
In class 5, the $RMSE_z$ should be $\leq$ .30 ft ($Accuracy_z \leq$ .60 feet)
In all classes combined, the $RMSE_z$ ***should*** *be $\leq$ .61 ft ($Accuracy_z \leq$ 1.19 feet)*

10 Miscellaneous
The contractor shall retain the original raw lidar and a copy of the processed lidar for at least 5 years, and must contact SAGIS before removing or deleting data.
All data should be delivered on USB/Firewire drives of 500 GB minimum.

Please contact Jason Lee at jlee@thempc.org or 912-651-1493, or Noel Perkins perkinsn@thempc.org , 912-651-1476, with any questions.