TEXAS NATURAL RESOURCES INFORMATION SYSTEMS
A DIVISION OF THE TEXAS WATER DEVELOPMENT BOARD

Texas Water Development Board

Texas Strategic Mapping Program

Lidar Specification

Version XIII

Texas Strategic Mapping Program Goals

It is the intent of the Texas Strategic Mapping Program (StratMap) to purchase geospatial data products that will provide direct savings, efficiencies, and cost duplication avoidance through inter-governmental collaboration and partnerships. The StratMap Contract is instrumental to these goals. Both the StratMap Program and the StratMap Contract are administered by the Texas Natural Resources Information System (TNRIS), a division of the Texas Water Development Board (TWDB).

Accuracy and Quality of Products

The StratMap Program, through the StratMap Contract, uses prequalified commercial data providers to collect and process geospatial data and separately selects third party quality assurance consultants, as needed, to review products and processes. Each participant in the program is expected to maintain internal quality controls and assurances to minimize errors and document procedures to ensure the data will meet or exceed requirements.

Project Phase Overview

		Lidar Vendor	QA/QC Vendor
Phase I		**PRE-FLIGHT PLANNING**	
		Kick-Off Meeting	
	Lidar Tasks	*Develop flight operations plan*	
		System calibration and geodetic control validation	
	Lidar Deliverables	**Schedule**	Review and comment
		Flight plan	
		Ground control plan	
		Sensor calibration reports	
Phase II		**DATA ACQUISITION**	
	Lidar Tasks	*Perform flight setup and geodetic control process*	*Collect QA/QC checkpoint survey*
		Fly project area to collect data	
		Verify data after each flight mission	
		Collect checkpoint survey	
	Lidar Deliverables	**Flight trajectories (lidar only) and GPS report**	Review and comment
		Checkpoint table and survey report	
		Data acquisition status updates	
Phase III		**DATA PROCESSING**	
	Lidar Tasks	*Boresight/calibration*	
		Point classification	
		Intensity image production	
		Generate hydro-flattening breaklines	
	Lidar Deliverables	**PILOT**	**Review Pilot and comment**
		All-return point cloud	Review data deliverables and comment
		Hydro-flattening breaklines	
		Intensity images	
		Re-submit Phase III deliverables as necessary	Approve or reject deliverables
		FINAL PRODUCT DEVELOPMENT	
	Lidar Tasks	*Create bare-earth DEM*	

Phase IV		*Generate metadata*	
	Lidar Deliverables	**DEM Raster**	Review and comment
		Metadata	

		Re-submit Phase IV deliverables as necessary	Approve or reject deliverables
			Deliver whole QA/QC checkpoint table to TWDB
			Submit final QA/QC report
		Data processing status updates	
	Project Closeout Meeting		

Lidar Data Specification

Lidar Specification	
Intellectual Property Rights	
The contracting agency shall have unrestricted rights to all delivered reports and data. All lidar products will become the property of the City of Marble Falls, TPWD, and TNRIS. All lidar products will be put in the public domain and accessible from the **Texas Natural Resources Information System**, a division of the Texas Water Development Board.	
Spatial Reference Framework	
Vertical Datum	NAVD88 with most recent NGS-approved geoid to convert from ellipsoidal to orthometric heights
Horizontal Datum	NAD83 (2011)
Projection	UTM
Vertical Units	Meters (Orthometric, NAVD88)
Horizontal units	Meters
The projection must be **defined** (viewable to the data user in stakeholder software) for every lidar product.	
Lidar Pre-Flight Planning and Data Acquisition	
Project Requirements	
Nominal pulse spacing (NPS)	**NPS ≤ 0.500 m**, or point density **≥ 4 points per m^2** for first-return data
Uniformity*	Spatial distribution of points must be uniform and free from clustering. 90% of cells in a 1meter grid will contain at least one first-return point. See Data voids for exclusions.
Buffer	**300 meter buffer** surrounding the AOI is required for flight planning and acquisition, with no buffer needed in between tiles. Buffer will not be included in final delivery.

Multiple returns*	Lidar sensor shall be capable of at least three (3) returns per pulse, including first and last returns. Multiple returns from a given pulse shall be stored in sequential order and point families must remain intact. For Geiger mode systems, see attached document.		
Return attributes	Each return must include: easting, northing, elevation, intensity, order of return (i.e. first return, second-return), classification, and Adjusted GPS Time. Easting, northing, and elevation must be recorded to the nearest **0.01 m** and GPS second reported to the nearest microsecond (or better). May include additional attributes. No duplicate entries.		
Scan angle	For lidar systems with an oscillating mirror, scan angle should not exceed ±20 degrees from nadir. Total field of view or full scan angle ≤ 40°. Rotating mirror systems are exempt from this requirement, but provider must provide planning of additional flight lines or other measures over dense urban areas to mitigate shadowing voids resulting from use of a FOV > 40°.		
Swath overlap	Minimum 30% overlap on adjoining swaths.		
Metadata			
Format	Tile-level metadata consisting of separate XML files paired with each data tile as well as project-level metadata for non-tiled data in XML format.		
FGDC Standard	All metadata shall be consistent with the Federal Geographic Data Committee's Content Standards for Digital Geospatial Metadata		
Methodology	Metadata will include processing steps and software used. If requested, sample metadata will be provided by TWDB.		
Data voids*	Data voids are defined as areas > $[(4*NPS)^2]$ with no first-return points. Data voids are unacceptable unless caused by water bodies or areas of low near-infrared (NIR) reflectivity (i.e. wet asphalt). No voids between swaths.		
Survey conditions	Leaf-off and no significant snow cover or flood conditions, unless approved by TWDB. Must be cloud, smoke, dust and fog-free between the aircraft and ground.		
GPS Procedures and Accuracy			
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. Report accuracies in metadata as compiled to meet the specified vertical accuracy at the 95% confidence level in open terrain according to the National Standard for Spatial Data Accuracy (NSSDA). Refer to Lidar Accuracy Assessment for details on QA/QC accuracy testing.		
Acquisition GPS procedures	At least two (2) GPS reference stations in operation during all missions, sampling positions at 1 Hz or higher frequently. Differential GPS baseline lengths shall not exceed 40 km, unless otherwise approved. Differential GPS unit in aircraft shall sample position at 2 Hz or more frequently. Lidar data shall only be acquired when GPS PDOP is ≤ 4 and at least 6 satellites are in view.		
Geodetic control	Lidar vendor must supply ground control for acquisition and processing. See Quality Assurance and Quality Control portion of TWDB SOW # 580-20-SOW-004 for recommended collection guidelines.		
Accuracy: ASPRS Class 10cm*	Non-Vegetated	**$RMSE_z$**	**< 10 cm**
		$Accuracy_z$ 95%	< 19.6 cm
	Vegetated	$Accuracy_z$ 95%	< 29.4 cm
	Horizontal	$RMSE_r$	< 25.0 cm
	Relative Swath	Smooth Surface repeatability/ Swath overlap difference RMSEz	≤6cm/≤8cm

Lidar Data Processing and Final Product Development			
Fully Classified All-Return Point Cloud			
Format	All-return point cloud in fully-compliant LAS version 1.4. All points must be classified according to the ASPRS classification standard for LAS.		
Spatial reference	LAS files will use the Spatial Reference Framework according to project specification and all files shall be projected and defined.		
ASPRS Classifications Required	**Class 1. Unclassified** **Class 2. Bare-earth Ground** **Class 3. Low Vegetation**	**Class 4. Medium Vegetation** **Class 5. High Vegetation Class 6. Building** **Class 7. Low Point (noise)**	**Class 9. Water** **Class 14. Culverts** **Class 17. Bridge Decks** **Class 18. High Noise** **Class 20. Ignored Ground**

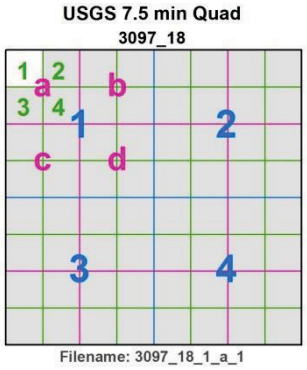
Withheld points*	Outliers, noise, blunders, geometrically unreliable points near the extreme edge of the swath, and other points deemed unusable are to be identified using the "Withheld" flag. This applies primarily to points which are identified during pre-processing or through automated postprocessing routines. Subsequently identified noise points may be assigned to the standard Noise Class (Class 7), regardless of whether the noise is lower or higher relative to the ground.
Overlap class*	The ASPRS Overlap Class (Class 12) shall **NOT** be used. All points must be classified unless identified as "Withheld".
Classification accuracy*	**Within any sample 1 km x 1 km area, no more than 1% of non-withheld points in the classes listed above** will possess a demonstrably erroneous classification value. This includes Unclassified points (Class 1) that should be correctly included in a different class as required by this specification. This requirement may be relaxed to accommodate collections in areas where the TWDB agrees classification to be particularly difficult.
Classification consistency*	Point classification shall 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.
Bare Earth Lidar / DEM Raster	
Format	Hydro-enforced 32-bit floating point raster DEM in (TBD at kick-off meeting) format to nearest 0.01-m is preferred, however similar raster formats may be permitted at the discretion of the TWDB.
Spatial reference	DEM files will use the Spatial Reference Framework according to project specification and all files shall be projected and defined for horizontal and vertical systems, including geoid model used.
Spatial resolution	**1-meter DO4Q tiles (See File Naming Convention)**
DEM tile buffer	All final DEM tiles should be delivered with a buffer that extends 50 meters around all four sides of the DEM tile. All final DEM tiles should have 90-degree corners, not rounded. The extents shall be computed by projecting the geographic corners and side midpoints to the required projection, then adding the buffer on each side of the resulting minimum bounding rectangle.
Quality	No seams, stepping, gaps, or quilting should be visible (unless naturally occurring), whether caused by differences in processing quality or character between tiles, swaths, lifts, or other non-natural divisions and will be cause for rejection of the entire DEM deliverable. There shall be no "plateau effect" from rounded or integer elevation values (must be floating point). Also see 'Data voids' under Project Requirements.

Artifacts	Vegetation, bridges, buildings, and other artifacts must be completely removed from Class 2 Bare-earth Ground. Artificial dams in waterways caused by bridges or other adjacent structures are not permitted with the exception of culverts. See 'Culverts and Bridges' under Hydro-flattening breaklines for more information.
Filtering	There shall be no over-aggressive filtering of the Ground class resulting in gaps or a degradation of DEM quality (e.g. hilltops shaved flat or data voids). There shall also be no under-aggressive filtering of the Ground class resulting in a degradation of DEM quality (e.g. portions of buildings or vegetation included in Ground or overly noisy surface).
Sinks	Depression sinks, natural or man-made (not erroneous), are **not** to be filled (as in hydroconditioning).
Breaklines	Hydrologic breaklines shall be used to define stream/river channels and water bodies allowing for unimpeded water flow. See Hydro-flattening breaklines below for more information.
No data	Acceptable internal voids and voids outside the project boundary shall be coded as a unique NODATA value identified within the raster file header.

Hydro-flattening Breaklines	
Format	All breaklines developed for use in hydro-flattening shall be delivered as a non-tiled Esri feature class for the entire AOI in polygon and/or polyline shapefile or geodatabase format. Waterbodies (ponds, lakes, and reservoirs), wide streams and rivers ("double-line"), and other non-tidal waterbodies are to be hydro-flattened within the DEM, resulting in a flat and level bank-to-bank gradient. The entire water surface edge must be at or below the immediately surrounding terrain. Bare-earth lidar points that are near the breaklines (proximity not to exceed NPS) shall be classified as Ignored Ground (class value equal to 10).
Spatial reference	Breakline feature class will use the Spatial Reference Framework according to project specification and shall be projected and defined.
Stream resolution	Hydro-flattening shall be applied to all streams that are nominally wider than **15.25 meters(~50 feet)**, and to all non-tidal boundary waters bordering the project area regardless of size. Stream features should be made continuous even when a segment narrows below this threshold for a distance of at least 1600 meters to maintain cartographic integrity. Flattened rivers and streams shall present a gradient downhill water surface, in accordance with the immediately surrounding terrain. In cases of drought, flood or rapidly moving water demonstrating conditions where the water surface is notably not level bank to bank, the water surface will be represented as it exists during acquisition while maintaining an aesthetic cartographic appearance.
Waterbody resolution*	Hydro-flattening shall be applied to all water impoundments, natural or man-made, that are nominally larger than **2 acres** in area. Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations drop when moving downstream, are required to be treated as rivers.
Non-tidal boundary waters*	Represented only as an edge or edges within the project area; collection does not include the opposing shore. Water surface is to be flat and level, as appropriate for the type of water body (level for lakes; gradient for rivers). The entire water surface edge must be at or below the immediately surrounding terrain.

Tidal waters*	Tidal water bodies are defined as water bodies such as oceans, seas, gulfs, bays, inlets, salt marshes, large lakes, and the like. This includes any water body that is affected by tidal variations. Tidal variations over the course of a collection or between different collections will result in lateral and vertical discontinuities along shorelines. This is considered normal and these anomalies should be retained. The final DEM is required to represent as much ground as the collected data permits. Water surface is to be flat and level, to the degree allowed by the irregularities noted above Scientific research projects in coastal areas often have specific requirements with regard to how tidal land-water boundaries are to be handled. For such projects, the requirements of the research will take precedence.
Islands*	Permanent islands 4,000 m^2 (1 acre) or larger shall be delineated within all water bodies.
Culverts and Bridges	Stream channels should break at road crossings (culvert locations). These road fills in Class 14 Culverts should not be removed from the DEM. However, streams and rivers should not break at elevated bridges. Bridges should be removed from the DEM (see 'Artifacts' under Bare Earth Lidar/DEM Raster). When the identification of a feature such as a bridge or culvert cannot be made reliably, the feature should be regarded as a culvert.

Intensity Images	
Format	Raster image of first-return intensity values in an acceptable format.
Spatial reference	Intensity images will use the Spatial Reference Framework according to project specification and all files shall be projected and defined.
Spatial resolution	**≤ 1-meter DO4Q tiles**
Image tile buffer	All final image tiles should have a buffer that extends 50 meters around all four sides of the image tile. All final image tiles should have 90-degree corners, not rounded. The extents shall be computed by projecting the geographic corners and side midpoints to the required projection, then adding the buffer on each side of the resulting minimum bounding rectangle.
Radiometric resolution	Unsigned 8-bit, 16-bit or 32-bit (highest available). Intensity images should typically contain original digital number (DN) values ranging from 0 - 100 or greater for ≥ 80% of areas with diverse land cover conditions.
Histogram	Histogram should be very close to normally distributed with minimal or no clipping.
Consistency	Images should be consistent in contrast and tone across project AOI. There should be no striping, tiling, or banding across project AOI.

File Naming Convention	
	Applies to the following: **All-return point cloud in LAS** **Bare-earth DEM** **Intensity images** **Tile-level metadata** Structure for data listed above shall conform to: 1/64th USGS 7.5-minute quadrangle Quarter-quarter-quarter quadrangle **(DOQQQQ, or DO4Q)** Structure shall be as follows: stratmap17-nps_DO4Qstring For example: **stratmap20-50cm_3098011a1**

Lidar Deliverables	
Phase I Deliverables	
Schedule	**Project timeline (schedule) with projected milestones should also include due dates for BOTH Phase III and Phase IV, to be separated by at least six weeks for QA/QC.** Schedule should be provided to TWDB in a PDF, .docx, or .xlsx format.
Flight plan	Flight plan for each AOI shall include: aircraft flight lines and GPS base stations in use during acquisition delivered in ESRI feature class, shapefile, or kmz/kml format.
Ground Control Plan	Planned ground control and checkpoints on graphic map(s) and delivered in shapefile or kmz/kml format.
Sensor Calibration Report	Most recent calibration report for all lidar sensors used for collection.
Phase II Deliverables	
Flight trajectories	Smoothed Best Estimate of Trajectory (SBET) files with recorded aircraft position (easting, northing, elevation) and attitude (heading, pitch, and roll) and Adjusted GPS time recorded at
	regular intervals of 1 second or less and delivered in ESRI feature class or shapefile format. May include additional attributes.
Flight report	Flight report should include at a minimum the following mission parameters: sensor make and model, nominal ground sampling distance, scan angle, average groundspeed, laser pulse rate, scan rate, and average flying altitude. Network parameters with base station IDs and location should be included as well as flight PDOP.
Control table	Any checkpoints collected by the lidar vendor for internal quality control shall be provided to TWDB in an electronic table (.csv and .shp) including State Plane (4202) coordinates (X,Y,Z) to three (3) decimal places, point ID and land cover type, at a minimum.
Control survey report	Along with control table, lidar vendor shall submit associated survey report including at a minimum selected geodetic control network and spatial parameters (i.e. coordinate system, geoid model).
Phase III Deliverables	
Pilot Data	The lidar vendor (in consultation with TWDB and project partners) will select a minimum of four (4) contiguous tiles within the project AOI which shall serve as a Pilot area. The Pilot will be delivered to TWDB and the QA/QC review consultant and shall include all-return point cloud, DEM and intensity image products delivered in final product form to meet or exceed the specifications established in this document. It is recommended that processing of other data in the AOI be suspended until the Pilot data have been approved by TWDB.
All-return point cloud	To be received by QA/QC review consultant on or before Phase III Deliverables due date. See section above titled ***Phases III & IV: Data Processing and Final Product Development*** for details. Final products must pass QA/QC review before acceptance.
Hydro-flattening Breaklines	
Intensity images	
Phase IV Deliverables	
DEM raster	To be received by QA/QC review consultant on or before Phase IV Deliverables due date. See section above titled ***Phases III & IV: Data Processing and Final Product Development*** for details. Final products must pass QA/QC review before acceptance.
Metadata	

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