PROJECT REPORT

Middle Pearl-Strong River Basin

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Prepared for

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1 PROJECT OVERVIEW

Fugro as a subconsultant to MGI was authorized to undertake this project, as a part of Work Order No. 112, dated November 1, 2012, issued to MGI in accordance with the terms and conditions of the Professional Services Agreement between MGI and the Mississippi Department of Environmental Quality (MDEQ), dated February 17, 2004. This Light Detection and Ranging (LiDAR) dataset is a survey of the Middle Pearl-Strong River Basin in Rankin and Simpson Counties, Mississippi. The project area consists of approximately 973 square miles.

The acquisition, processing, and delivery of classified point cloud data, LiDAR intensity data, hydro-flattened breaklines, and bare earth DEM covering Middle Pearl-Strong River Basin, MS was a coordinated effort between Fugro and MGI to support MDEQ's Mississippi Digital Earth Model (MDEM) program. The mission of MDEQ is to safeguard the health, safety, and welfare of present and future generations of Mississippians by conserving and improving our environment and fostering wise economic growth through focused research and responsible regulation.

The project design of the LiDAR data acquisition was developed to support a nominal post spacing of 1 meter. Fugro acquired 73 flight lines in six lifts on January 6, 7, 31, and February 1, 2013. The data was divided into 5000 by 5000 foot cells that serve as the tiling scheme. LiDAR data collection was performed with a Cessna 310 twin-piston aircraft, utilizing a Leica ALS60 MPiA sensor, collecting multiple return x, y, and z as well as intensity data. LiDAR data is remotely sensed high-resolution elevation data collected by an airborne collection platform. This data of the Middle Pearl-Strong River Basin was collected at sufficient resolution to provide a nominal point spacing of 1 meter for collected points. Up to 4 returns were recorded for each pulse in addition to an intensity value. Products delivered to MGI include the following: 1) classified point cloud data in LAS v.1.2 format; 2) LiDAR intensity data in GeoTIFF format; 3) hydro-flattened breaklines in ESRI shapefile format; 4) bare earth LiDAR data in GeoTIFF raster format; 5) tile index in shapefile format; and 6) LiDAR project report in PDF format.

2 GROUND CONTROL AND BASE STATIONS

Flight crews and GPS survey crews were in communication to ensure the GPS constellations had an adequate number of satellites above the horizon to ensure sufficient Position Dilution of Precision (PDOP).

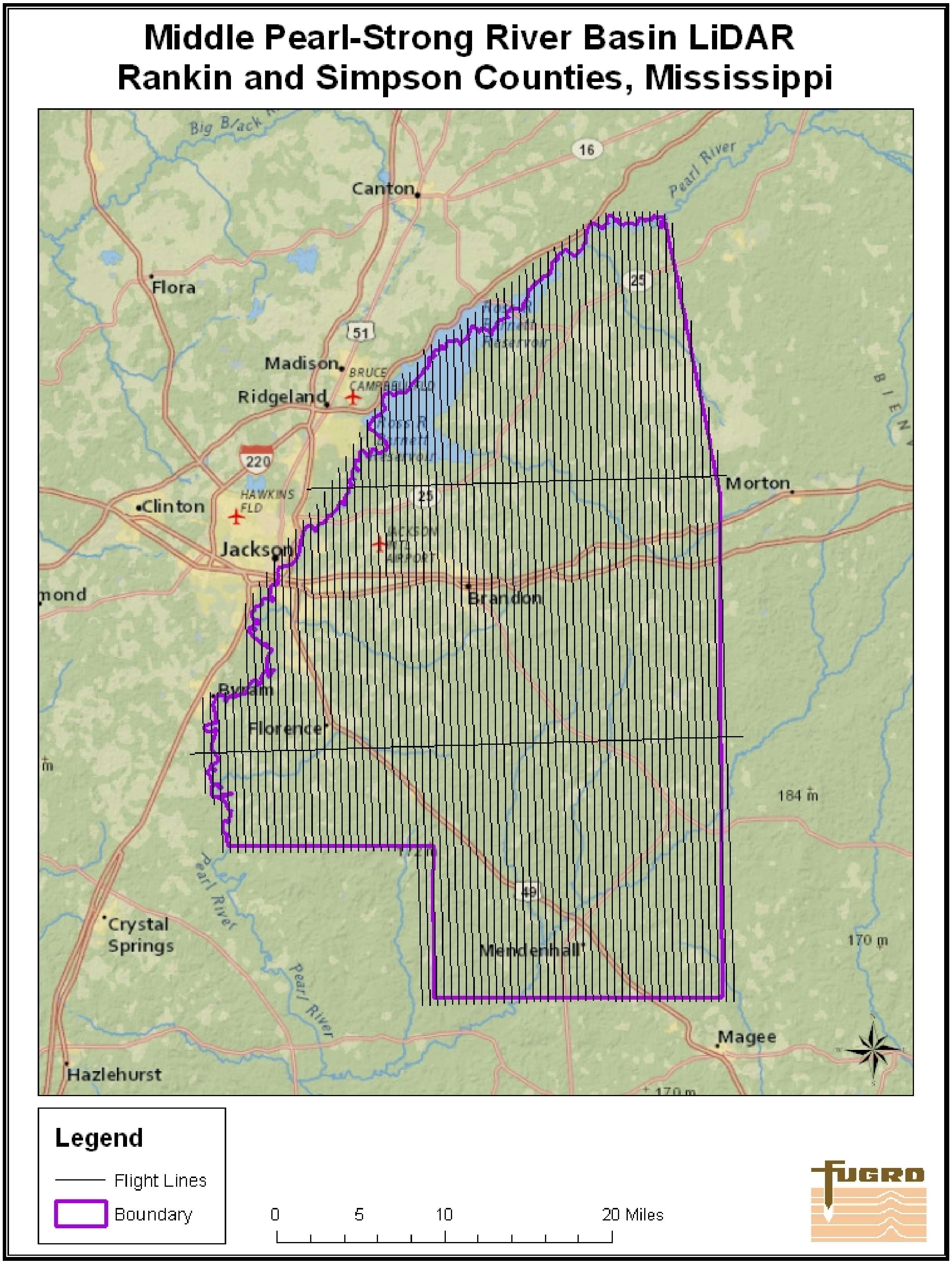
All surveying activities were performed by Waggoner Engineering, Inc. (Waggoner). Waggoner collected twenty eight (28) ground control points to support the LiDAR collection.

3 DATA ACQUISITION / COLLECTION

3.1 Collection Area

The collection area included a 100-meter buffer. The resulting project boundary was modified after collection due to portions of the Pearl River being cut-off in the original, buffered boundary.

The below graphic is a visual of the flight lines with the final project boundary.


Middle Pearl-Strong River Basin LiDAR
Rankin and Simpson Counties, Mississippi
Canton
Flora
Madison
Ridgeland
Clinton
Jackson
Brandon
Morton
Byram
Florence
Crystal Springs
Mendenhall
Magee
Hazlehurst
Pearl River
Legend
Flight Lines
Boundary
0
5
10
20 Miles

3.2 LiDAR Data Acquisition Considerations

Fugro planned all aircraft operations to be undertaken Hawkins Field Airport KHKS in Jackson, MS. LiDAR data was acquired using a twin engine aircraft equipped with an antenna and receiver for airborne GPS collection. Flight status was communicated during data collection.

Data was collected when environmental conditions met the criteria specified. To be specific, the following conditions existed prior to launch of the aircraft:

- Leaf-off
- Streams and rivers were within their normal banks
- Cloud free
- Air traffic restrictions were accounted for

3.3 Description of the Laser Scanning System

For this project, Fugro utilized the Leica ALS60 MPiA (Multiple Pulse in the Air) laser scanning measurement system. The ALS60 MPiA System is capable of recording four range points, and three intensity values for each emitted laser pulse. The ALS60 MPiA is a state-of-the-art LiDAR sensor with the following operational specifications:

- Variable field of view from 5° to 75° (Field of view and altitude combination allow variable swath widths).
- Up-to 200 kHz laser pulse rate (200,000 pulses per second).
- Altitude capability of 200 meters to 5000 meters AMT.

The LiDAR system has a wide operational window and can be operated at night, to facilitate data acquisition in high traffic areas where daytime flight restrictions may be imposed.

The sensor can adequately produce the required 1 meter NPS.

3.4 Project Design

To achieve a project scope with a NPS of 1 meter, Fugro acquired 71 north/south flight lines to cover the 973 square mile AOI with 2 east/west cross tie flight lines perpendicular to the main flight lines. The following is detail on the LiDAR acquisition covering the Middle Pearl-Strong River Basin AOI:

Collections: 06

Collection Dates: January 6, 7, 31, and February 1, 2013

Number of Lines: 71 north/south, 2 east/west cross tie flight lines

Field of View (FOV): 34 degrees

AMT: 5,741 feet

Sensor Type: Leica ALS60

Sensor Serial Number: 142

Please refer to Attachment A: Flight Logs for further details.

4 DESCRIPTION OF LIDAR PRODUCTION PROCESSES

4.1 Verification of Data Usability

All acquired LiDAR data went through a preliminary review to assure that complete coverage was obtained and that there were no gaps between flight lines before the flight crew left the project site. Once back in the office, the data is run through a complete iteration of processing to ensure that it is complete, uncorrupted, and that the entire project area has been covered without gaps between flight lines. There are essentially three steps to this processing.

4.1.1 GPS/IMU Processing

Airborne GPS and IMU data was immediately processed using the airport GPS base station data, which was available to the flight crew upon landing the plane. This ensures the integrity of all the mission data. These results were also used to perform the initial LiDAR system calibration test.

4.1.2 Raw LiDAR Data Processing

Technicians processed the raw data to LAS format flight lines with full resolution output before performing QC. A starting configuration file is used in this process, which contains the latest calibration parameters for the sensor. The technicians also generated flight line trajectories for each of the flight lines during this process.

4.1.3 Verification of Coverage and Data Quality

The following steps and quality control measures verify complete coverage and ensure data quality:

- Technicians checked flight line trajectory files to ensure completeness of acquisition for project flight lines, calibration lines, and cross flight lines.
- The intensity images were generated for the entire lift at the required 1 meter nominal post spacing (NPS) for the project.
- The technician visually checked the intensity images against the project boundary to ensure full coverage.
- The intensity histogram was analyzed to ensure the quality of the intensity values.
- The technician also thoroughly reviewed the data for any gaps in project area.
- The technician generated a sample TIN surface to ensure no anomalies were present in the data.
- Turbulence was inspected for and if it affected the quality of the data, the flight line was rejected and reflown.
- The technician also evaluated the achieved post spacing against project specified 1 meter NPS.

4.2 LiDAR Data Processing

Data processing includes the following three production steps for generating the final deliverables:

- Raw data processing and boresight
- Pre-processing
- Post-processing

Quality control steps are incorporated throughout each step and are described in the following sections.

4.2.1 Raw Data Processing and Boresight

The boresight for each lift was done individually as the solution may change slightly from lift to lift. The following steps describe the Raw Data Processing and Boresight process:

- The technician processed the raw data to LAS format flight lines using the final GPS/IMU solution. This LAS data set was used as source data for boresight.
- The technician used commercial software to calculate initial boresight adjustment angles based on sample areas selected in the lift- mini project. These areas cover calibration flight lines collected in the lift, cross tie, and production flight lines. These areas are well distributed in the lift coverage and cover multiple terrain types that are necessary for boresight angle calculation. The technician then analyzed the result and made any necessary additional adjustment until it is acceptable for the mini project.
- Once the boresight angle calculation is complete for the mini project, the adjusted settings were applied to all of the flight lines of the lift and checked for consistency. The technician utilized commercial and proprietary software packages to analyze the matching between flight line overlaps for the entire lift to ensure that systematic errors are minimized for the lift and the results meet project requirements.
- Once all lifts are completed with boresight adjustment individually, the technician checked and corrected the vertical misalignment of all flight lines and also the matching between data and ground truth.
- The technician ran a final vertical accuracy check of the boresighted flight lines against the surveyed ground control points after the z correction to ensure the accuracy requirement of 18.5cm RMSE was met; see Attachment B: Accuracy Assessment Report for results.

4.2.2 Pre-processing

Once boresighting is complete for the project, the project was set up for automatic classification first. The LiDAR data was cut to production tiles. The flight line overlap points, Noise points and Ground points were classified automatically in this process.

4.2.3 Post-processing

Fugro has developed a unique method for processing LiDAR data to identify and re-classify elevation points falling on vegetation, building, and other above ground structures into separate data layers. The steps are as follows:

- Fugro utilized commercial software as well as proprietary software for automatic filtering. The parameters used in the process were customized for each terrain type to obtain optimum results.
- Once the automated filtering was completed, the files were run through a visual inspection to ensure that the filtering was not too aggressive or not aggressive enough. In cases where the filtering was too aggressive and important terrain features were filtered out, the data was either run through a different filter within local area or was corrected during the manual filtering process.
- Interactive editing was completed in visualization software which provides manual and automatic point classification tools. Fugro utilized commercial and proprietary software for this process. Vegetation and artifacts remaining after automatic data post-processing were reclassified manually through interactive editing. The hard edges of ground features that were automatically filtered out during the automatic filtering process were brought back into ground class during manual editing. The technician reviewed the LiDAR points with color shaded TINs for anomalies in ground class during interactive filtering.
- All LAS tiles went through peer review after the first round of interactive editing was finished. This helps to catch misclassification that may have been missed by the interactive editing.
- After the manual editing and peer review, and finalization of bare earth filtering, all tiles went through another final automated classification routine. This process ensures only the required classifications are used in the final product (all points classified into any temporary classes during manual editing were then re-classified into the project specified classifications).

- The classified LiDAR point cloud work tiles went through a water classification routine based on the collected water polygons. Also, during this process, the points originally classified as flight line overlap went through an automated classification to filter ground points and low points inside overlap areas.

4.3 Product Development

4.3.1 Classified Point Cloud Data

Once manual inspection, QC and final autofilter is done for the LiDAR tiles, the LAS data was packaged to the project specified tiling scheme, clipped to project boundary and LAS delivery format. The tiles were re-projected to the Mississippi State Plane Coordinate System, West Zone, NAD83(2011), US Survey Feet; NAVD88, US Survey Feet, using GEOID12A. The file header was formatted to meet project specifications with File Source ID assigned. This Classified Point Cloud product was used for the generation of derived products.

This product was delivered in fully compliant LAS v1.2, Point Record Format 1 with Adjusted Standard GPS Time. Georeference information is included in all LAS file headers. Intensity values are included for each point. Each tile has unique File Source ID assigned. The Point Source ID matches to the flight line ID in flight trajectory files.

The following classifications are included:

(01) Code 1 – Processed, but unclassified
(02) Code 2 – Bare-earth ground
(03) Code 7 – Noise (low or high, manually identified, if needed)
(04) Code 9 – Water
(05) Code 10 – Ignored Ground (Breakline Proximity)
(06) Code 11 – Withheld

4.3.2 LiDAR Hydro Breakline Collection

Hydro linework was produced by initially running automated 2D waterbody detection process then manually reviewing and correcting the vectors using classified LiDAR datasets. The 3D process ensures the downhill flow of the rivers along with the perpendicular flattening of the banks. The waterbodies were flattened to a constant elevation.

The hydrographic features were collected as separate feature types. The following hydro features were collected as Waterbody Banklines:

- <u>Inland Ponds and Lakes:</u> Edges of non-flowing (static) waterbodies, ~ 2 acres, flattened with the same elevation
- <u>Rivers:</u> Edges of flowing waterbodies, 100-feet nominal width and over 0.5 mile in length
- <u>Non-Tidal Boundary Waters:</u> Edge or edges within the project area
- <u>Islands:</u> 1 acre

The hydro breaklines were delivered in ESRI shapefile format. The coordinate system of the ESRI shapefile dataset is Mississippi State Plane, West Zone, NAD83(2011), NAVD88, US Survey Feet.

4.3.3 Bare Earth Surface (Raster DEM)

The hydro-flattened bare earth DEM was generated using the bare earth points, as well as the 3D hydro breaklines. Once the deliverable LAS files were generated for the entire project area and QC'ed, and 3D breaklines were collected and QC'ed, they were used to produce the hydro-flattened bare earth DEM. The bare earth points that fell within 1*NPS along the hydro breaklines were classified as Class 10 so that these points were excluded from the DEM generation process. This process was done in batch mode using Fugro proprietary software.

The technician used in-house software for the production of LiDAR-derived hydro-flattened bare earth DEM surface in initial grid format. Hydro-flattening was applied to all water impoundments, natural or man-made, that are larger than 2-acres in area and to all rivers that are nominally wider than 100-feet. This process was done in batch.

The hydro-flattened bare earth DEM that was generated in initial grid format was then clipped to the approved boundary. Once the initial, hydro-flattened bare earth DEM was generated, the technician checked the tiles to ensure that the grid spacing meets specifications. The technician also checked the surface to ensure proper hydro-flattening. The entire data set was checked for complete project coverage. Once the data was checked, the tiles were then converted into a GeoTIFF raster format for delivery.

4.3.4 Intensity Images

Fugro's Leica ALS60 LiDAR sensor recorded the raw return intensity for every range. This intensity value represents the peak voltage of the return signal as recorded by the LiDAR system controller. There are several external factors which influence this value. Among the most significant factors include the range to the target, angle of incidence and atmospheric dispersion. In addition, the system controller also records the state of the AGC (automatic gain control) scaled to an 8-bit value. The AGC circuit, as the name implies, adjusts the return signal gain in response to changes in target reflectance. The gain and intensity values may vary over a scene and from day to day. The overall goal of normalization is to adjust the intensity value for contributing factors leaving only variations that are the direct result of the material spectral response. LiDAR intensity images were generated in TerraSolid software. The data was balanced in Photoshop, cut to the approved tile layout, and clipped to the approved project boundary. The entire data set was checked for complete project coverage. The Geo-Referencing information was assigned to the GeoTIFF header using proprietary software. The Intensity Images were provided in grayscale 8-bit GeoTIFF format.

5 ATTACHMENTS

5.1 Attachment A: Flight Logs

AttachmentA_MiddlePearl-StrongRiverBasin_FlightLogs.pdf

5.2 Attachment B: Accuracy Assessment Report

AttachmentB_MiddlePearl-StrongRiverBasin_AccuracyAssessmentReport.pdf