Lidar Acquisition and Processing Report

USGS CONTRACT:	**G16PC00029**
CONTRACTOR:	**Merrick-Surdex JV**
TASK ORDER NUMBER:	**G17PD00008**
TASK NAME:	**NE Sandhills Lidar Project**

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Project Overview

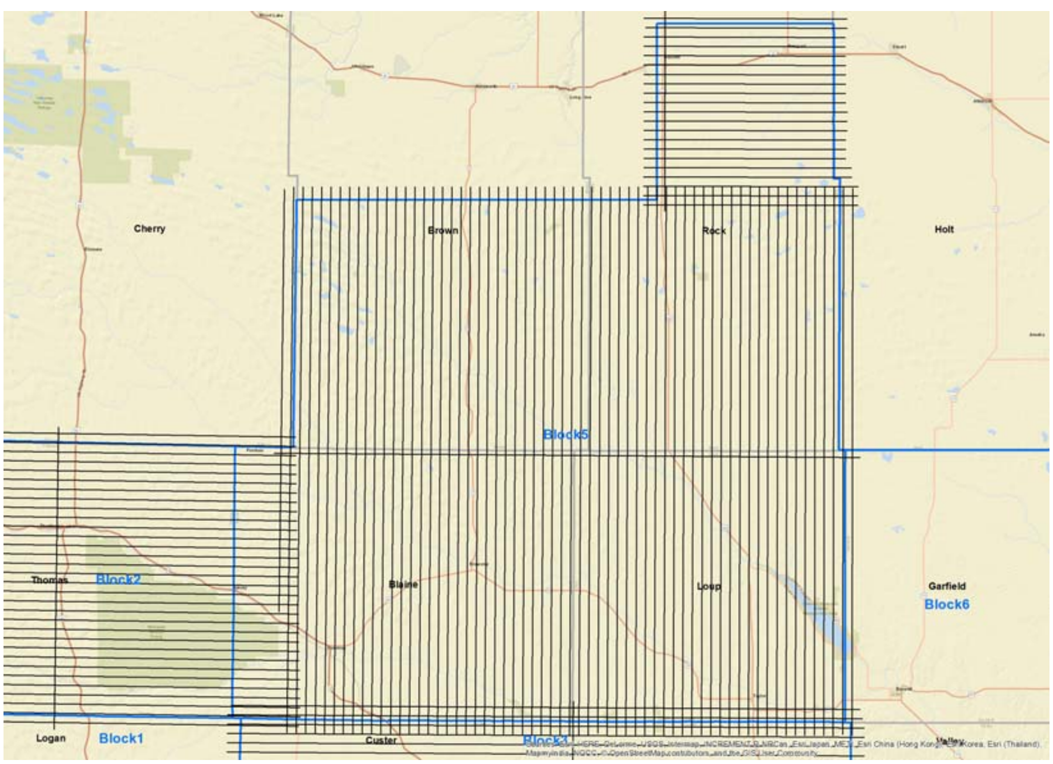
The United States Geological Survey (USGS) contracted with Merrick-Surdex Joint Venture in December of 2016 to collect high resolution Lidar elevation data over multiple counties in Sandhills Region of north-central Nebraska. This project will follow the USGS National Geospatial Program Lidar Base Specification, Version 1.2 and Quality Level 2 standards. The total project area covers over 18,111 square miles. This report covers the collection of Lidar data for over 2,600 square miles in the following Block-5 counties: Blaine, Loup, Brown & Rock.

Lidar Data Planning and Acquisition:

The following parameters were used for the Lidar acquisition.

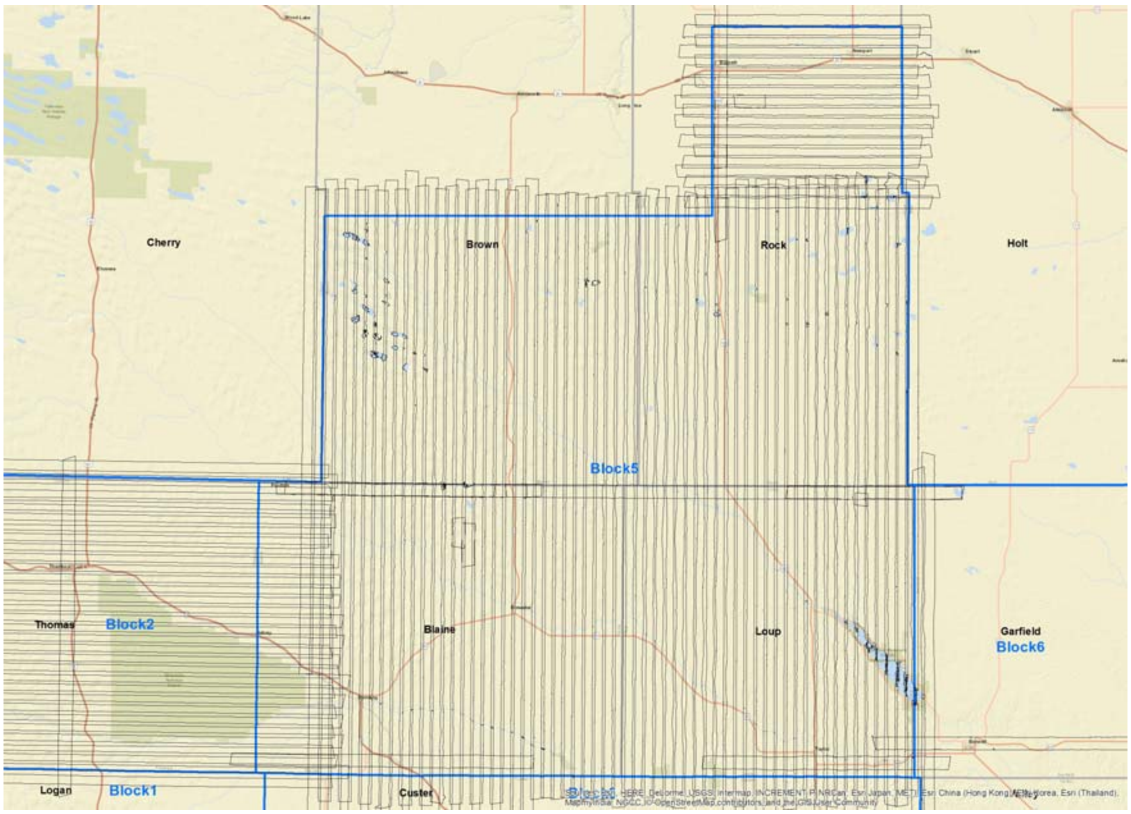
Flight altitude	~9,400' AMSL
Airspeed	~150 knots
Full swath width	1657 meters
Overlap between strips	20 % (average)
Field of View	45.0 degrees
Nominal Point Spacing	0.71 meters
Nominal Point Density	2.0 pts/meter
Scan frequency	54.0 Hz
Returns per pulse	4 + intensity

The following graphic shows the Block-5 planned Lidar lines:



Lidar data was acquired leaf-off, snow-free and while water bodies are at below to normal levels by Surdex from December 23, 2016 to June 2, 2017. Surdex utilized their single engine Cessna 206 with Optech Galaxy-5060382 multi-pulse sensor. Surdex set up GPS base stations for all flights at or near Ainsworth or Rock County Regional Airports. All flight lines were within 40 miles of a GPS station.

The following graphic shows the actual flown Block-5 Lidar lines:



The flight crew is guided by a GPS controlled flight management system, which displays the flight plan; including altitude, heading, cross track deviation and PDOP. During the flight mission, the system operator monitors flight management data, laser information, to ensure a successful mission.

Additional swaths, though not strictly necessary for meeting point density or project coverage requirements, are acquired for every project area. These additional swaths are often referred to as “cross strips”. A number of cross strips are included in critical locations and in sufficient number that the combination of the normal production swaths and the cross strips constitutes a geometrically stable “block” of Lidar coverage. The additional swaths are used for instrument calibration and project block adjustment purposes. The Lidar cross strips serve a purpose that is analogous to the use of cross strips in a photogrammetric bundle adjustment, providing additional redundant observations of the ranging data that can be used for QC and adjustment of the data from the Lidar acquisition mission(s).

All data in the aircraft, including GPS, IMU (inertial measurement unit, i.e. rotational angles); laser ranges; are recorded onto removable hard drives and flash memory cards. Upon landing the system operator removes all storage devices from the LIDAR system and the GPS receivers. At the end of each flight day, all is transmitted (via FTP and/or FED-EX) to the office for processing.

Data Processing

Post processing of Lidar involves the following software packages and procedures:

1. POSPac MMS (Applanix)
2. GrafNet (Waypoint)
3. LMS Manager (Optech)
4. TerraScan, TerraModeller, TerraMatch (TerraSolid)
5. GeoCue (NIIRS10)

Once the mission data arrives from the field, it is immediately archived and enters into a QC process. The real time airborne GPS/IMU data is combined with the Lidar range data to produce preliminary Lidar swaths. The preliminary swaths are used to generate interim raster products for review and QC operations. The data is compared with the project boundary, planned flight lines, and previously collected swaths. The swath data is checked for gaps to verify complete data coverage. Any areas of missed coverage, coverage of insufficient point density, or showing any collection anomalies are identified and queued for re-flight before the flight crew leaves the project area.

After initial QC has completed, the mission’s airborne GPS data is differentially processed using GPS base station data, blended with the IMU data, and the integrity of the blended solution is verified. The blended GPS/IMU data is combined with the laser range data and instrument calibration parameters to produce raw swath files in the target/project coordinate system. The use of current instrument calibration settings enables the process to account for and correct all systematic sensor errors from the raw swath files for each mission.

The calibrated swath files from one or more missions next undergo a block adjustment to produce final swath files. The block adjustment process accomplishes three distinct goals. 1) It uses the Lidar cross strips to detect and correct any non-modeled (residual) sensor errors in the calibrated swath data. 2) It uses all overlapping swath data to detect and correct GPS/IMU position and orientation (relative) errors. 3) It uses adjacent adjusted swath data (if present) and ground control points (if present) to detect and correct (absolute) positioning errors in the Lidar point data. The final block adjustment ensures that all inter-swath discrepancies within the block are minimized and that all discrepancies with adjacent blocks of coverage and with ground control are minimized.

Ground Surface filtering and classification:

After the LAS files have been processed through block adjustment, they were loaded into Geocue and tiled into manageable units or working tiles. A senior Lidar analyst reviews the project to determine the correct macros and algorithms to apply for each unique block. Several sources were used to determine the best algorithms to apply for each area. These include landcover classification polygons, slope rasters and available imagery. Once blocks are identified a senior Lidar analyst chose several working tiles and applied the best classification macro for the identified area. The analyst runs several iterations of the macro to produce the best results within each category. Once the macros are refined and the results evaluated, the macro was assigned and ran on all working tiles within the block. This process is replicated for each unique processing block. Data integrity is assured by Lidar technicians reviewing each working tile. Technicians built multiple shaded relief images for data review and profile any areas of suspect classification. Technicians can also make minor classification adjustments to the LAS files using specialized Lidar tools developed internally for bare earth processing.

All of the laser points are stored in a database that retains information about flight day, time, return number, laser scan angle, and other information. The database is reviewed and areas of like characteristics are delineated and flagged. The LIDAR processing group determined which type of filtering techniques need to be applied to each type of area, to provide the best quality at ground elevation surface. Factors that affect this decision are slope, vegetation and cultural features. Each project has unique characteristics that can only be assessed after the data is collected. Data integrity is assured after visualizing results from the selected filtering techniques such as shaded relief models, 3-D viewers and elevation images.

All Lidar data processing followed the USGS Version 1.2 Base Lidar Specifications. Surdex used a combination of automated and manual filtering techniques for the creation of the bare-earth surface. A minimum 95% of the artifacts, outliers, voids, systematic and random errors, noise, anomalies, manmade features and vegetation were removed. The resulting digital terrain model will support production of 1' contours for ASPRS Class I Standards. The final step involves output of data into LAS version 1.4 format. All final LAS data were projected into the following: UTM Zone 14 NAD83, NAVD88 Geoid12B, meters.

Create Hydro-Flattening Breaklines

Surdex has a wide variety of tools available for the compilation of breaklines required for the hydro-flattening services. Surdex's R&D staff has developed proprietary software to assist and improve efficiency in the hydro-flattening process. Several data sources are available to assist the technicians in developing the hydro-flattening breaklines. These sources include; color hill shade maps derived from the Lidar data, NHD vectors, intensity images and current existing imagery are all useful in developing the hydrological breaklines. Surdex has proven that using custom color hill shade rasters in ArcMap is superior for both accuracy and efficiency in breakline compilation. The custom hill shades provide a much more intelligent representation of the bare earth surface allowing for precise determination of hydrological features.

Using the custom hill shades, GIS technicians digitized breaklines representing water features consisting of ponds/lakes greater than ~2 acres and streams/rivers wider than ~100 feet per the guidelines for hydro flattened derivative products. To improve efficiency, the various data sets described above may be used as a guide directing the technician to areas containing hydro features and providing confirmation of the features as determined in the hill shades. The hydro-flattening is applied to ponds, again using Surdex proprietary applications, by converting the 2-D breaklines to 3-D lines. This was accomplished by draping the digitized hydrological features to the bare earth surface and at the discretion of the technicians, based on terrain relief, to apply either a "lowest elevation" or "average elevation" to the 3-D breakline.

Hydro-flattening of streams and rivers is similar to impoundments in that the initial compilation is again derived from the hill shades as described above. Technicians compile 2-D breaklines at the edges of rivers and streams using techniques and resources as described above. For river/stream features, however, rather than applying an average or lowest point elevation to the breaklines, technicians compile a profile centerline to be used in determining elevation. The 3-D shapefile centerline is processed through the Surdex application applying elevations to the breaklines at vertices perpendicular to the centerline creating 3-D breaklines. By applying consistent elevations to both sides of the rivers/streams, hydro-flattening produces a level surface perpendicular to the stream in the correct direction of flow. All breaklines will be delivered as PolylineZ or PolygonZ features compatible with GIS and CAD software.

Create Digital Elevation Models

The final 1-meter resolution Imagine Digital Elevation Models (DEM) were created once the data had been calibrated, edited and filtered using our workflows described above. This DEM represents the ground surface, interpolated using the gridded network from the bare earth surface. Water Bodies (ponds and lakes), wide streams and rivers, and other non-tidal water bodies will be hydro-flattened within the DEM.
Hydro-flattening was applied to all water impoundments, natural or man-made, that are larger than ~2 acres in area (equivalent to a round pond ~350' in diameter), to all streams wider than ~100', and to all non-tidal boundary waters bordering the project area regardless of size. Areas outside survey boundary shall be coded as "No Data". Internal voids (e.g., open water areas) will be coded as "No Data".

All final Imagine DEM files and hydro data were generated into the following projection: UTM Zone 14 NAD83, NAVD88 Geoid12B, meters using butt-matched 1,000x1,000 meter tiles.

The following graphic show the 1,000 meter tile index coverage for Block-5: