LiDAR Survey of Parts of Potomac and Susquehanna Rivers
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1. LiDAR System Description and Specifications

This survey was performed with an Optech 2033 Airborne Laser Terrain Mapper (ALTM) serial number 98b110 mounted in a twin-engine Cessna 337 Skymaster aircraft (Tail Number N337P). The instrument nominal specifications are listed in table 1.

Operating Altitude	330 - 2000 meters
Range Accuracy	10 cm single shot
Range Resolution	1 cm
Relative Accuracy	5-10 cm @ 33KHz
Options	Intensity data; First and Last Pulse Measurements; Extended Altitude (2000 M)
Scan Angle	Variable from 0 to +/- 20
Angle accuracy	0.05 degrees
Angle Resolution	0.01 degrees
Scan Frequency	Variable - product of scan rate and scan frequency must be <590
Pulse Rate Frequency	33 KHz
Roll and Pitch Accuracy	0.04 degrees
Heading Accuracy	0.05 degrees
Laser Wavelength	1047 nanometers
Beam Divergence	0.30 mrad

Table 1 – Optech ALTM 2033 specifications.

See http://www.optech.ca for more information from the manufacturer.

2. Area of Interest.

The survey area consisted of two polygons: 1) over a portion of the Potomac River in Washington D.C. enclosing 60 square km; and 2) over a portion of the Susquehanna River in Pennsylvania enclosing 23 square km. The survey areas are shown below in Figures 1 and 2.

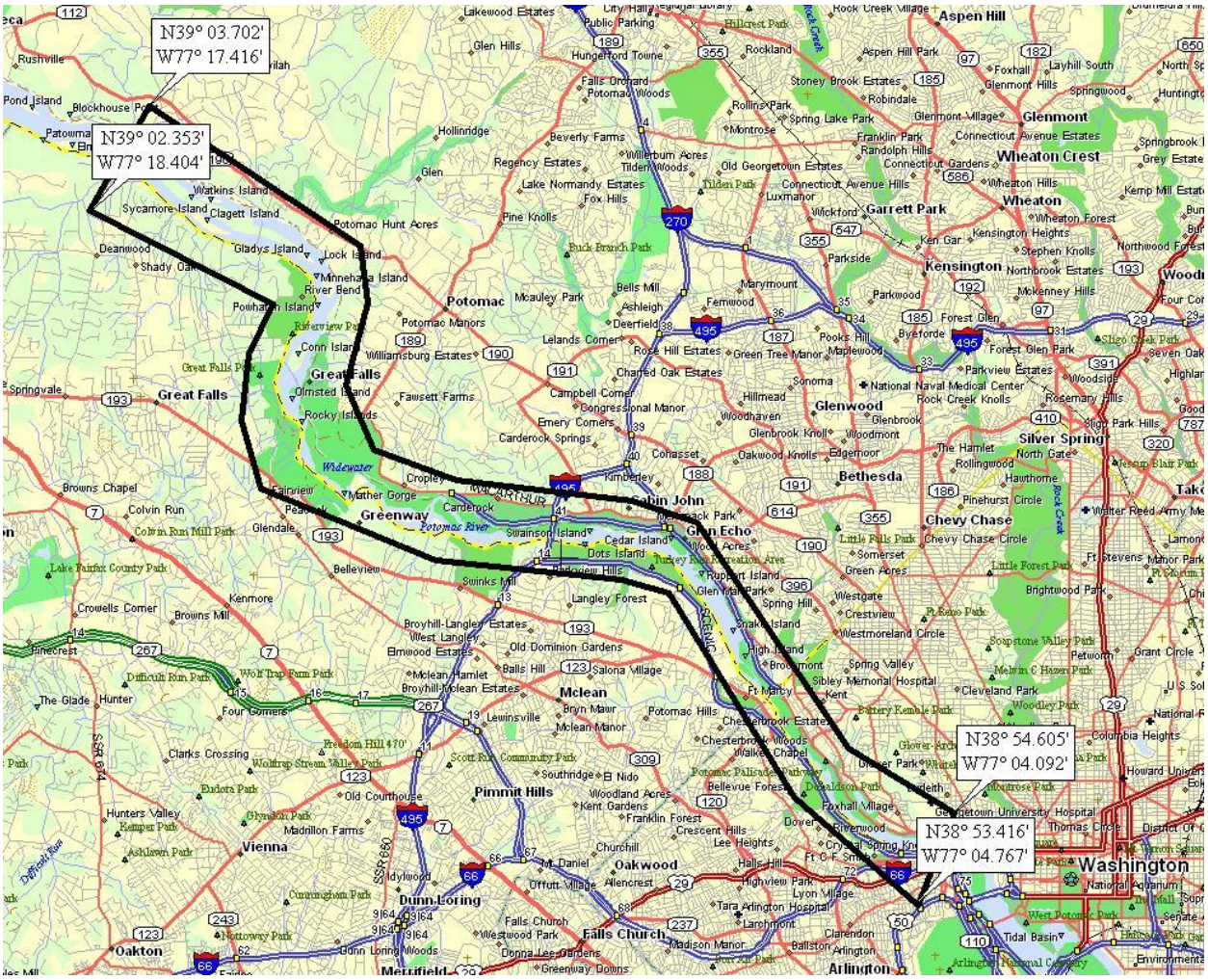

Figure 1 – Location of survey polygon on the Potomac River. (Delorme).

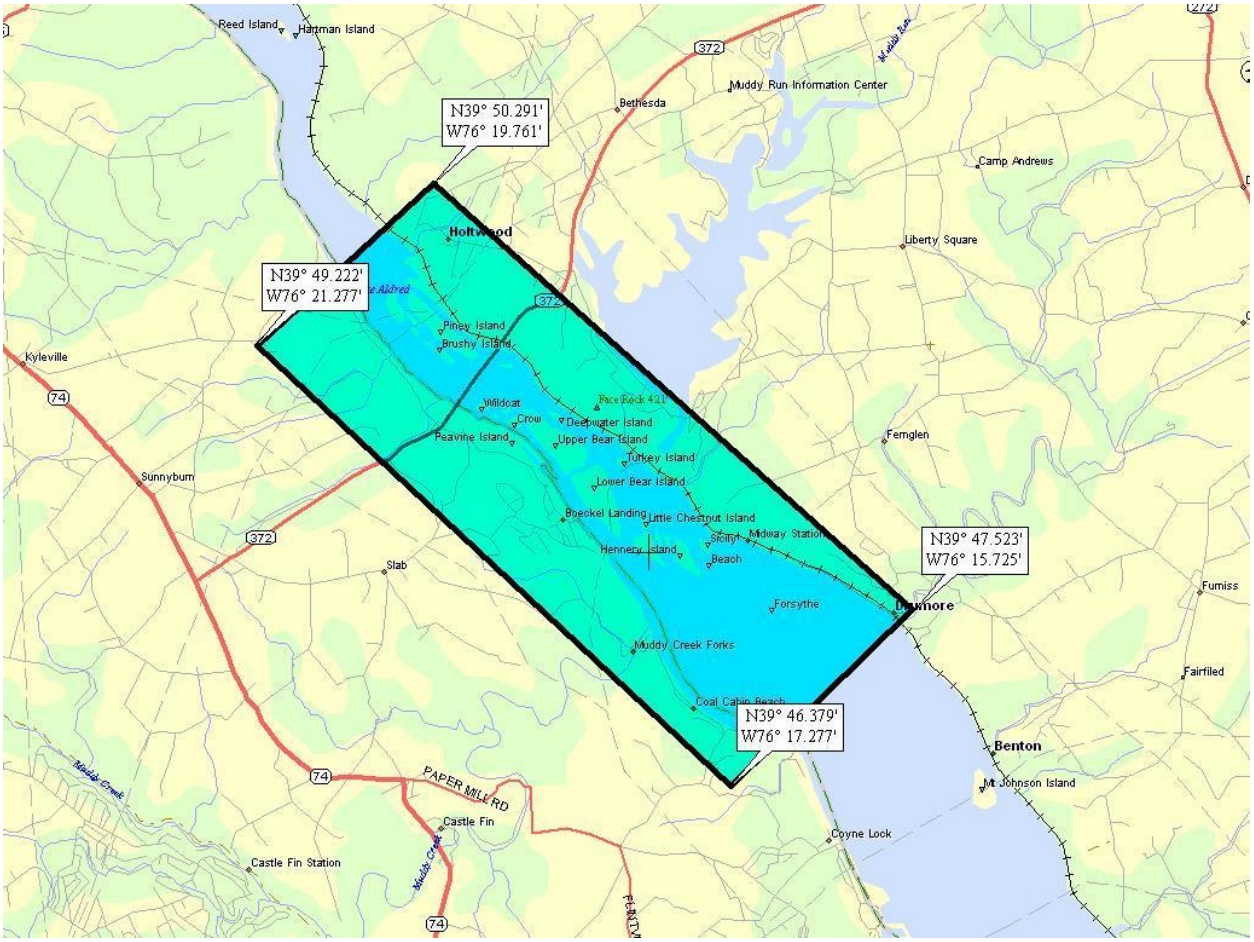

Figure 2 – Location of survey polygon on the Susquehanna River. (Delorme).

3. Data Collection

a) Survey Dates: The Susquehanna survey took place on January 9, 2005 (DOY 009) and the Potomac survey took place on January 11, 2005 (DOY 011).

b) Airborne Survey Parameters: The survey parameters for the Susquehanna survey are provided in Table 2 below

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	600 m	Laser PRF	33.3 kHz	Total Flight Time	2.4 hrs
Flight Speed	60 m/s	Beam Divergence	0.30 mrad	Total Laser Time	0.6 hrs
Swath Width	436 m	Scan Frequency	28 Hz	Total Swath Area	25 km^2
Swath Overlap	50%	Scan Angle	± 20°	Total AOI Area	22.0 km^2
Point Density	1.4 p/m^2	Scan Cutoff	1°		

Table 2 – Susquehanna Survey Parameters and Totals.

c) Airborne Survey Parameters: The survey parameters for the Potomac survey are provided in Table 3 below

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	750 m	Laser PRF	33.3 kHz	Total Flight Time	5.0 hrs
Flight Speed	60 m/s	Beam Divergence	0.30 mrad	Total Laser Time	1.5 hrs
Swath Width	545 m	Scan Frequency	28 Hz	Total Swath Area	76 km^2
Swath Overlap	50%	Scan Angle	± 20°	Total AOI Area	52.0 km^2
Point Density	1.1 p/m^2	Scan Cutoff	1°		

Table 3 – Potomac Survey Parameters and Totals.

d) Ground GPS (Susquehanna Survey): Three GPS reference station locations were used during the survey: LANC, SUSQ, and YORK. Two of these stations (LANC, SUSQ) were set by NCALM. YORK is part of the national CORS network (see http://www.ngs.noaa.gov/CORS/ for more information). All of the reference stations collected GPS observations at 1 Hz. Table 4 gives the coordinates of the stations.

GPS station	LANC	SUSQ	YORK
Operating agency	NCALM	NCALM	PADT
Latitude	40.1166989	39.8254051	39.9870213
Longitude	-76.2934641	-76.3084843	-76.740494
Ellipsoid Height (m)	84.080	139.310	99.720

Table 4 – GPS Coordinates of ground reference stations for Susquehanna survey

e) Ground GPS (Potomac Survey): Four GPS reference station locations were used during the survey: NAIL, DIRT, ZDC1, and GAIT. Two of these stations (NAIL, DIRT) were set by NCALM. ZDC1 and GAIT are part of the national CORS network (see http://www.ngs.noaa.gov/CORS/ for more information). All of the reference stations

collected GPS observations at 1 Hz except for GAIT which was interpolated to 1 Hz in post-processing. Table 5 gives the coordinates of the stations.

GPS station	NAIL	DIRT	ZDC1	GAIT
Operating agency	NCALM	NCALM	FAA	NGS
Latitude	39.0773963	39.0773877	39.1015875	39.1339835
Longitude	-77.5556621	-77.5556899	-77.5427410	-77.2209774
Ellipsoid Height (m)	84.063	83.957	81.292	109.054

Table 5 – GPS Coordinates of ground reference stations for Potomac survey

4. GPS/IMU Data Processing

Reference coordinates for all NCALM stations are derived from observation sessions taken over the project duration and submitted to the NGS on-line processor OPUS which processes static differential baselines tied to the international CORS network. For further information on OPUS see http://www.ngs.noaa.gov/OPUS/ and for more information on the CORS network see http://www.ngs.noaa.gov/CORS/

Airplane trajectories for this survey were processed using KARS (Kinematic and Rapid Static) software written by Dr. Gerald Mader of the NGS Research Laboratory. KARS kinematic GPS processing uses the dual-frequency phase history files of the reference and airborne receivers to determine a high-accuracy fixed integer ionosphere-free differential solution at 1 Hz. All final aircraft trajectories for this project are blended solutions from all stations.

After GPS processing, the trajectory solution and the raw inertial measurement unit (IMU) data collected during the flights are combined in APPLANIX software POSProc. POSProc implements a Kalman Filter algorithm to produce a final, smoothed, and complete navigation solution including both aircraft position and orientation at 50 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory).

5. LiDAR Data Processing Overview

LiDAR point-cloud processing was done in Optech REALM software, ASCII is the only supported output format.

Calibration of roll, pitch, and scanner mirror scale was done manually using cross-lines flown perpendicular to project lines.

Classification of the point cloud into two classes – ground and non-ground_ was performed by automated routines using software developed by researchers at the UF and by Optech software.

NCALM makes every effort to produce the highest quality LiDAR data possible but every LiDAR point cloud and derived DEM will have visible artifacts if it is examined at a sufficiently fine level. Examples of such artifacts include visible swath edges, corduroy (visible scan lines), and data gaps.

A detailed discussion on the causes of data artifacts and how to recognize them can be found here:
http://ncalm.berkeley.edu/reports/GEM_Rep_2005_01_002.pdf .
A discussion of the procedures NCALM uses to ensure data quality can be found here:
http://ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf
NCALM cannot devote the required time to remove all artifacts from data sets, but if researchers find areas with artifacts that impact their applications they should contact NCALM and we will assist them in removing the artifacts to the extent possible – but this may well involve the PIs devoting additional time and resources to this process.

6. Accuracy Assessment

Over 2000 check points were collected by vehicle-mounted GPS on paved roads nearby to the Leesburg Municipal airport and then surveyed with the ALTM at the start of the survey flight. The RMS of the height differences between these check points and their nearest neighbor LiDAR point was 0.065 meters.

7. Data Deliverables

a) **Horizontal Datum**: NAD83(CORS96)
b) **Vertical Datum:** GEOID 03
c) **Projection:** UTM Zone 18N
d) **File Formats:**

1. Point Cloud in 9-column flight strips (1 file per flight strip) ASCII format (TXYZiXYZi) Last stop data in columns 2-5; first stop data in columns 6-9
2. Point cloud data in 3-column (XYZ) ASCII tiles.
3. ESRI format elevation rasters at 1-M cell size.