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Date: April 7, 2008

Subject: Report of Vertical Accuracy Testing of LiDAR Data for LandAirWoolpert Lidar Block

Project Name: PAMAP
Product Tested: LiDAR DTM
State Plane Zone: Pennsylvania North and South NAD83
Production Block: LandAirWoolpert Block, 2006
Accepted/Rejected: Accepted
Production Company: BAE

Counties in Production Block:

- Elk
- Cameron
- Clearfield
- Centre
- Cambria
- Blair
- Clinton

References:

a. FGDC Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy (NSSDA), 1998.

b. Appendix A, *Guidelines for Aerial Mapping and Surveying*, to FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners," April, 2003.

c. Guidelines for Digital Elevation Data, version 1.0, National Digital Elevation Program (NDEP), May 10, 2004.

d. ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data, version 1.0, May 24, 2004.

e. PAMAP QAQC Work Plan, version 3, February 7, 2008.

Reference a. The NSSDA implements a statistical and testing methodology for estimating the positional accuracy of points on maps and in digital geospatial data, with respect to georeferenced ground positions of higher accuracy, reported at the 95% confidence level. The NSSDA replaces the 1947 National Map Accuracy Standard (NMAS) for digital geospatial data. The NMAS is applicable to graphic maps, as accuracy is defined by map scale and/or contour interval. The NSSDA was developed to report accuracy of digital geospatial data that are not constrained by scale or contour interval. The NSSDA uses root-mean-square-error (RMSE) methodology which assumes that all errors follow a normal error distribution.

Reference b. FEMA guidelines require LiDAR data to be tested separately in three or more major land cover categories representative of the area mapped.

References c and d. The NDEP and ASPRS guidelines were developed specifically for LiDAR data, after recognition that errors in a bare-earth LiDAR digital terrain model (DTM) do not necessarily follow a normal error distribution. LiDAR DTM errors usually follow a normal error distribution in open terrain, including urban areas with asphalt or concrete surfaces, so that RMSE methodology is applicable for what is called Fundamental Vertical Accuracy (FVA); but LiDAR DTM errors in vegetated terrain may depart from the normal error distribution because of non-standard differences in penetration of dense vegetation for which bare-earth DTM errors may also be non-standard. For such areas, the 95th percentile errors are used to define Supplemental Vertical Accuracy (SVA) in each of the individual land cover categories and Consolidated Vertical Accuracy (CVA) for all land cover categories combined.

Reference e. PAMAP's QAQC Work Plan requires LiDAR data to be tested in accordance with Acceptance Criteria 69a, 69b and 70 listed in Reference e. Criterion 69a refers to the NSSDA and FEMA guidelines (References a and b). Criterion 69b refers to the NDEP and ASPRS guidelines (References c and d). In accordance with this criterion Dewberry is testing the checkpoints in Open Terrain only for an accuracy equivalent to 2ft contours (Fundamental Vertical Accuracy = 1.19ft at 95% confidence level) and the checkpoints in all categories for an accuracy equivalent to 4ft contours (Consolidated Vertical Accuracy = 2.38ft at 95% confidence level). Criterion 70 also refers to the FEMA guidelines (Reference b).

The QA/QC checkpoints were surveyed by Herbert, Rowland & Grubic, Inc. (HRG) consistent with procedures to achieve 5-cm vertical accuracy at the 95% confidence level. Each QA/QC checkpoint location was selected per guidelines published in references, b, c and d. Dewberry determined the Δz differences in elevations (orthometric heights) between the ground-surveyed QA/QC checkpoints and elevations interpolated from the LiDAR DTM for those coordinates. Dewberry then computed the root-mean-square-error ($RMSE_z$) and other accuracy statistics for each land cover category for vertical accuracy testing in accordance with NSSDA and FEMA guidelines. Dewberry also computed the FVA, SVA, and CVA statistics for vertical accuracy testing in accordance with NDEP and ASPRS guidelines. The NSSDA computes $Accuracy_z$ (vertical accuracy at the 95% confidence level) based on $RMSE_z$ x 1.9600; because FVA is also computed by this method, $Accuracy_z$ is the same as FVA in open terrain. However, $Accuracy_z$ in vegetated terrain will rarely equal CVA or SVA in vegetated terrain because the CVA and SVA are computed using the 95th percentile error rather than $RMSE_z$ x 1.9600. As shown at Tables 1 and 2, Dewberry tested vertical accuracy by both the NSSDA/FEMA and NDEP/ASPRS methods to ensure that all accuracy specifications were satisfied and to help determine the degree to which vertical errors do not follow a normal error distribution.

Table 3 shows that all of the acceptance criteria in the PAMAP QA/QC Work Plan were satisfied.

Table 1. Vertical Accuracy Statistics per NSSDA/FEMA Guidelines

100 % of Totals	RMSE (ft) Open Terr. Spec=0.61ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	0.54	0.22	0.12	2.70	0.49	100	-0.54	2.99
Open Terrain	0.34	0.11	0.12	0.26	0.33	19	-0.40	0.73
High Grass	0.31	0.14	0.11	0.61	0.28	21	-0.26	0.81
Brush	0.74	0.44	0.15	1.53	0.61	20	-0.11	1.99
Forest	0.74	0.34	0.30	3.32	0.68	20	-0.54	2.99
Urban	0.35	0.07	-0.05	1.42	0.36	20	-0.31	0.89

Table 2. Vertical Accuracy Statistics per NDEP/ASPRS Guidelines

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=1.195 ft	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=2.38 ft	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=2.38 tf
Consolidated	100		0.90	
Open Terrain	19	0.67		0.68
High Grass	21			0.57
Brush	20			1.63
Forest	20			0.70
Urban	20			0.83

Table 3. PAMAP Acceptance Criteria

PAMAP Acceptance Criteria			Tested
PASS	69a NSSDA/FEMA, $RMSE_z$	≤ 0.61 ft, Open Terrain	0.34 ft
PASS	69a NSSDA/FEMA, $Accuracy_z$	≤ 1.19 ft at 95% confidence level	0.67 ft
PASS	69b NDEP/ASPRS, FVA	≤ 1.19 ft at 95% confidence level	0.67 ft
PASS	69b NDEP/ASPRS, CVA	≤ 2.38 ft at 95% confidence level	0.90 ft

Table 4 summarizes the vertical accuracy computations for all checkpoints available for Land Air Lidar Block. Figure 1 shows the location of these checkpoints in the Block.

Table 4. Vertical Accuracy Computations

QA/QC Survey Checkpoints				LiDAR Elevations		Accuracy	
Surveyed by HRG				Measured by Dewberry		Calculations	
pointNo	easting	northing	elevation	zLidar	LandCoverType	DeltaZ	AbsDeltaZ
O1140	1919903.67	313218.16	1755.70	1755.30	Open Terrain	-0.40	0.40
O1645	1816502.13	289318.98	1767.60	1767.21	Open Terrain	-0.39	0.39
O1144	1986895.52	305078.27	642.30	642.02	Open Terrain	-0.28	0.28
O1114	1743237.16	420748.82	2063.20	2062.98	Open Terrain	-0.22	0.22
O1159	1690625.33	395334.78	1466.80	1466.64	Open Terrain	-0.16	0.16
O1651	1844581.43	293560.25	1639.60	1639.49	Open Terrain	-0.11	0.11
O1603	1765617.58	443201.01	2387.90	2387.82	Open Terrain	-0.08	0.08
O1119	1701816.87	461182.93	2107.10	2107.10	Open Terrain	0.00	0.00
O1124	1677183.77	203843.94	1365.00	1365.10	Open Terrain	0.10	0.10
O1628	2010646.19	249311.08	1248.30	1248.42	Open Terrain	0.12	0.12
O1636	2051998.86	267706.83	1146.90	1147.06	Open Terrain	0.15	0.15
O1135	1936430.79	271940.73	761.90	762.10	Open Terrain	0.20	0.20
O1166	1839099.57	489415.77	1018.30	1018.56	Open Terrain	0.26	0.26
O1613	1956428.61	223483.13	1073.40	1073.66	Open Terrain	0.26	0.26
O1633	2029883.51	258785.91	1214.00	1214.26	Open Terrain	0.26	0.26
O1621	1960352.95	247147.87	1034.60	1034.97	Open Terrain	0.37	0.37
O1612	1826301.45	252527.28	1587.40	1587.96	Open Terrain	0.56	0.56
O1608	1799420.25	239493.82	1573.20	1573.87	Open Terrain	0.67	0.67
O1607	1787715.87	232615.51	1579.50	1580.23	Open Terrain	0.73	0.73
H1167	1803440.33	476570.85	1191.20	1190.94	High Grass	-0.26	0.26
H1652	1854695.40	303355.62	1651.80	1651.60	High Grass	-0.20	0.20
H1170	1703491.95	470141.28	1438.20	1438.03	High Grass	-0.17	0.17
H1120	1699319.72	470596.58	1925.80	1925.68	High Grass	-0.12	0.12
H1640	1787325.90	310464.40	1134.70	1134.60	High Grass	-0.10	0.10
H1139	1916860.14	313590.60	1720.90	1720.80	High Grass	-0.10	0.10
H1650	1839961.33	286619.73	1623.70	1623.61	High Grass	-0.09	0.09
H1117	1705171.34	423045.04	2146.90	2146.94	High Grass	0.04	0.04
H1620	1966757.47	253796.65	937.10	937.15	High Grass	0.05	0.05
H1143	1982207.36	301737.14	677.40	677.46	High Grass	0.06	0.06
H1155	1698137.27	398353.12	1472.50	1472.61	High Grass	0.11	0.11
H1115	1739628.71	418194.73	2148.80	2148.97	High Grass	0.17	0.17
H1602	1768660.13	436117.02	1940.30	1940.49	High Grass	0.19	0.19
H1169	1756124.87	460668.07	1735.40	1735.67	High Grass	0.27	0.27
H1615	1982597.26	237395.00	1254.00	1254.28	High Grass	0.28	0.28
H1627	2004098.77	247684.71	1213.90	1214.20	High Grass	0.30	0.30
H1600	1779902.08	434227.92	1489.60	1489.96	High Grass	0.36	0.36
H1622	1913557.72	239982.83	1217.20	1217.57	High Grass	0.37	0.37
H1629	2021056.55	252496.13	1078.00	1078.49	High Grass	0.49	0.49
H1610	1808747.26	242538.01	1532.00	1532.57	High Grass	0.57	0.57
H1605	1769925.62	225418.04	1581.90	1582.71	High Grass	0.81	0.81
B1614	1972994.49	228683.50	1188.90	1188.79	Brush	-0.11	0.11
B1154	1692365.49	395189.69	1460.70	1460.60	Brush	-0.10	0.10
B1168	1758997.13	461737.76	1806.80	1806.85	Brush	0.05	0.05
B1142	1980495.06	299101.25	672.40	672.46	Brush	0.06	0.06
B1116	1730543.82	421113.54	1794.40	1794.46	Brush	0.06	0.06
B1626	1999261.42	246996.26	1252.80	1252.86	Brush	0.06	0.06
B1635	2052617.39	269277.57	1183.20	1183.28	Brush	0.08	0.08
B1125	1676969.42	490485.04	1439.10	1439.19	Brush	0.09	0.09
B1118	1675183.26	428951.68	2361.90	2362.01	Brush	0.11	0.11
B1141	1921574.43	313956.55	1740.20	1740.32	Brush	0.12	0.12

B1641	1799886.77	303619.64	1427.40	1427.59	Brush	0.19	0.19
B1634	2045078.38	264560.41	1134.40	1134.64	Brush	0.24	0.24
B1646	1828196.29	275255.48	1440.50	1440.84	Brush	0.34	0.34
B1171	1698723.90	464514.61	1381.50	1381.91	Brush	0.41	0.41
B1619	1973184.45	253328.71	1171.90	1172.37	Brush	0.47	0.47
B1653	1853742.94	302025.65	1594.70	1595.36	Brush	0.66	0.66
B1601	1779003.44	435178.39	1581.00	1582.09	Brush	1.09	1.09
B1606	1780256.55	229724.25	1347.10	1348.52	Brush	1.42	1.42
B1609	1805595.12	241977.43	1514.10	1515.71	Brush	1.61	1.61
B1611	1818241.34	248749.49	1467.10	1469.09	Brush	1.99	1.99
W1147	1987808.86	307753.14	677.00	676.46	Forest	-0.54	0.54
W1644	1812741.99	302697.96	1644.20	1644.00	Forest	-0.20	0.20
W1158	1711605.00	415602.30	1533.60	1533.51	Forest	-0.09	0.09
W1177	1711023.10	444804.23	2181.10	2181.13	Forest	0.03	0.03
W1656	1768274.44	299869.75	1113.70	1113.78	Forest	0.08	0.08
W1128	1786085.69	424352.71	1114.00	1114.11	Forest	0.11	0.11
W1174	1707567.71	452080.95	2051.20	2051.32	Forest	0.12	0.12
W1162	1760093.92	396372.21	1176.40	1176.56	Forest	0.16	0.16
W1134	1748390.29	446334.90	1741.80	1742.05	Forest	0.25	0.25
W1123	1695743.16	473191.45	1745.80	1746.08	Forest	0.28	0.28
W1649	1836248.13	285236.70	1624.70	1625.01	Forest	0.31	0.31
W1165	1804583.64	430300.82	1639.40	1639.72	Forest	0.32	0.32
W1131	1772969.48	436437.03	1677.20	1677.57	Forest	0.37	0.37
W1632	2026170.43	256839.28	1190.70	1191.07	Forest	0.37	0.37
W1618	1979710.32	247181.77	1807.90	1808.28	Forest	0.38	0.38
W1659	1726449.94	299647.71	1823.50	1823.91	Forest	0.41	0.41
W1113	1748784.58	418615.24	2283.70	2284.15	Forest	0.45	0.45
W1639	2067234.33	262808.17	1086.30	1086.79	Forest	0.49	0.49
W1138	1914406.63	313097.49	1733.80	1734.38	Forest	0.58	0.58
W1625	1923100.89	235021.71	1247.20	1250.19	Forest	2.99	2.99
UB7-9H	1682960.34	395478.93	1446.70	1446.39	Urban	-0.31	0.31
UB7-1H	1745940.49	454835.19	1767.10	1766.84	Urban	-0.26	0.26
UB5-19H	1743685.80	420279.15	2094.00	2093.77	Urban	-0.23	0.23
UB7-6H	1758991.00	291577.90	1149.50	1149.33	Urban	-0.17	0.17
UB7-17H	1698498.97	348721.17	1409.30	1409.16	Urban	-0.14	0.14
UB7-2H	1712774.99	489240.80	1600.80	1600.68	Urban	-0.12	0.12
UB6-9H	1934650.82	269441.89	769.80	769.71	Urban	-0.09	0.09
UB6-6H	1987092.24	241333.56	1291.30	1291.24	Urban	-0.06	0.06
UB7-7H	1652292.17	338164.81	1389.90	1389.85	Urban	-0.05	0.05
UB6-4H	1934622.54	221600.54	1184.30	1184.25	Urban	-0.05	0.05
UB7-13H	1736911.68	437481.49	1910.60	1910.55	Urban	-0.05	0.05
UB6-1H	1884422.75	231316.56	1001.80	1001.76	Urban	-0.04	0.04
UB6-8H	1962520.27	270495.75	933.40	933.37	Urban	-0.03	0.03
UB5-6H	1703636.27	484186.54	1825.10	1825.09	Urban	-0.01	0.01
UB5-7H	1698311.22	484973.05	1820.60	1820.64	Urban	0.04	0.04
UB5-14H	1698351.92	426997.33	2100.10	2100.22	Urban	0.12	0.12
UB5-20H	1751074.09	213698.83	1386.30	1386.89	Urban	0.59	0.59
UB5-4H	1804065.97	240834.78	1511.70	1512.30	Urban	0.60	0.60
UB5-1H	1834665.51	269305.93	1424.90	1425.73	Urban	0.83	0.83
UB5-3H	1800270.45	245368.76	1611.60	1612.49	Urban	0.89	0.89

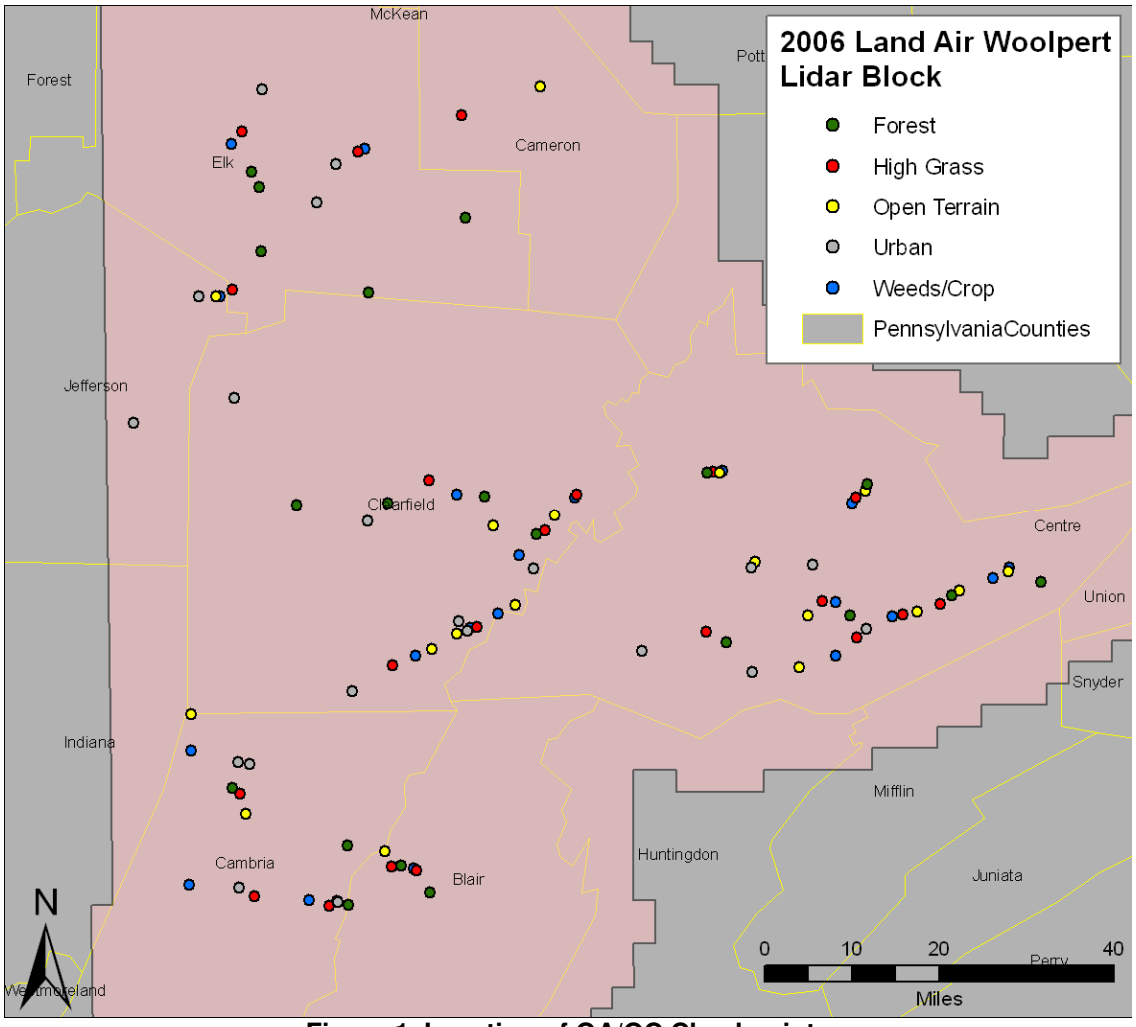

Figure 1. Location of QA/QC Checkpoints

Compared with the 1.19 foot specification for vertical accuracy equivalent to 2-foot contours in open terrain, tested 0.67 foot vertical accuracy at 95% confidence level in open terrain.

Compared with the 2.38 foot specification for vertical accuracy equivalent to 4-foot contours in all areas, tested 0.90 foot vertical accuracy at 95% confidence level in all land cover categories combined.

Approved by:

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