KENTUCKY STATEWIDE '12 LIDAR DATA ACQUISITION AND PROCESSING

POST-FLIGHT AERIAL ACQUISITION AND CALIBRATION REPORT

Photo Science Job Number: 7145-002

January 31, 2013

Completed by Photo Science, Inc.

PHOTO SCIENCE
Geospatial Solutions

Submitted by:
Photo Science
523 Wellington Way, Suite 325
Lexington, KY40503
Phone: (859) 277-8700 | Email: csmith@photoscience.com

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. SUMMARY / SCOPE

1.1. SUMMARY

This report contains a summary of the Kentucky Statewide '12 acquisition task order, issued by the State of Kentucky. The intent of this document is to only provide specific validation information for the LiDAR data acquisition/collection work completed for the project.

1.2. SCOPE

The scope of the Kentucky Statewide '12 LiDAR task order included the acquisition of aerial topographic LiDAR using state of the art technology, along with necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems, for the Area of Interest (AOI) covering the counties of Anderson, Bourbon, Boyle, Campbell, Franklin, Garrad, Grant, Hardin, Harlan, Harrison, Henry, Kenton, Knott, Letcher, Mercer, Nelson, Owen, Perry, Scott, Shelby, Spencer, Trimble and Woodford (with partial coverage of Bullitt, Caroll, Clark, Fayette, Gallatin, Jessamine, Lincoln, Madison, Meade, and Rockcastle). The aerial data collection was designed with the following specifications listed in Table 1 below.

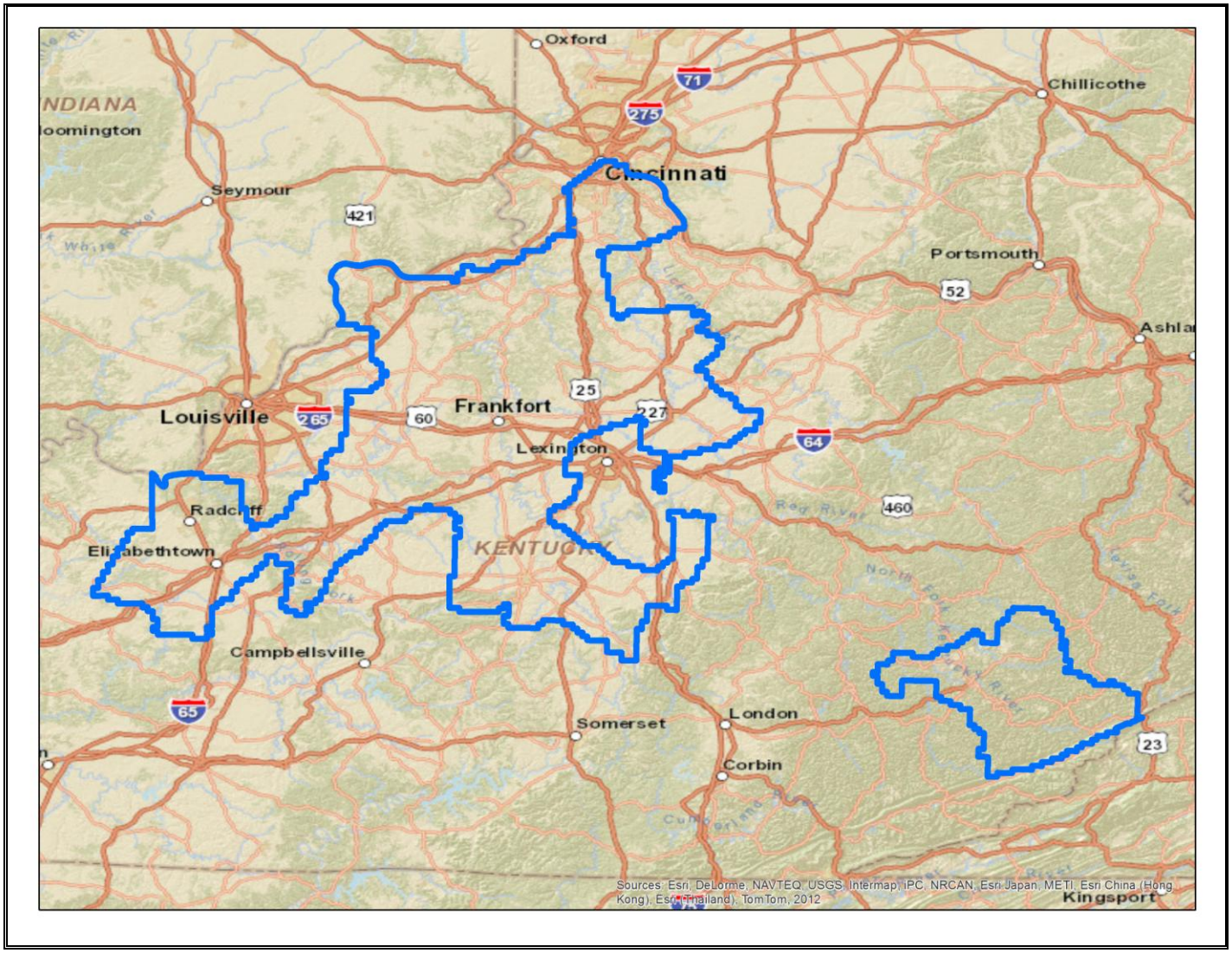
Table 1. Planned LiDAR Specifications

LiDAR				
Average Point Density	**Flight Altitude (AGL)**	**Field of View**	**Side Overlap**	**RMSEz**
1.00 pts / m^2	6000 ft	25.6 degrees	30%	12.5 cm or better

1.3. LOCATION / COVERAGE

The project boundary consists approximately 6,000 square miles as shown in Figure 1.

Figure 1. Kentucky Statewide '12 LiDAR Project Boundary



1.4. DURATION

There were fifty flight dates (several with multiple lifts) with first mission being flown on November 8, 2011 and the last mission being flown on January 19, 2013.

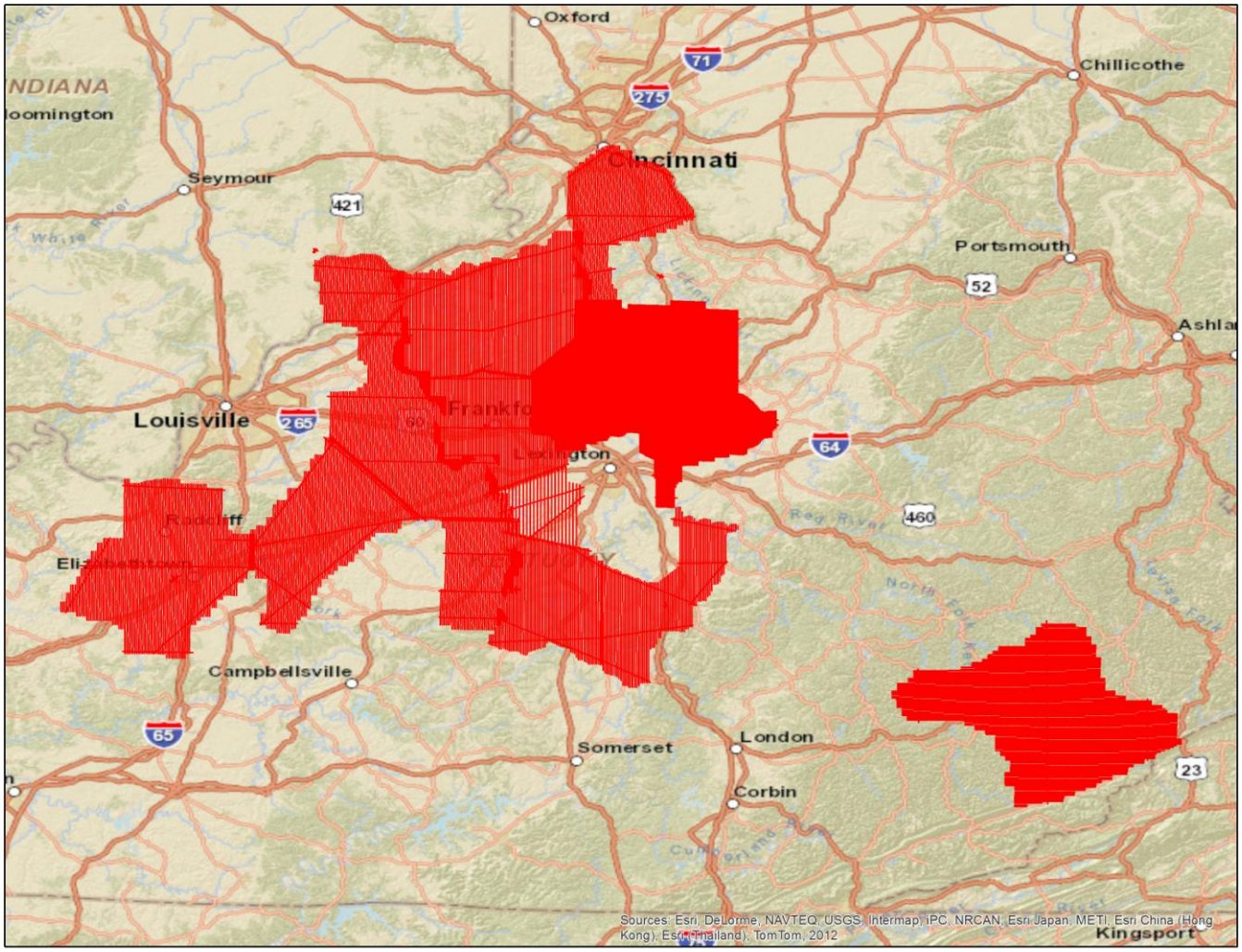
1.5. ISSUES

The primary issue of concerns with this task order was a combination of poor weather conditions and a compressed spring flying season due to the earlier than normal leaf on conditions. We were forced to acquire approximately 70% of the AOI in the spring and then complete acquisition during leaf off conditions in the late fall and early winter.

2. PLANNING / EQUIPMENT

The entire target area was comprised of 1025 planned flight lines and approximately 19837 flight line miles. Please refer to Figures 2 on the following page.

Figure 2. Planned Flight Lines: Overview



Detailed project flight planning calculations were performed for the Kentucky Statewide project using ALTM Nav and Mission Pro planning software. Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity. A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specification Table 2 below:

Table 2. LiDAR System Specifications

LiDAR System Specifications	
Terrain and Aircraft	**Flying Height AGL:** 1828 m; 6000 feet
	Recommended Ground Speed (GS): 116 kts
Scanner	**Field of View (FOV):** 25.6; degrees
	Scan Rate Setting used (SR): 30.1 Hz
Laser	**Laser Pulse Rate used:** 50 kHz
	Multi Pulse in Air Mode: Enabled
Coverage	**Full Swath Width:** 829.64 m
Point Spacing and Density	**Maximum Point Spacing Across Track:** 1.001 m
	Maximum Point Spacing Along Track: 0.997 m
	Average Point Density: 1.00 pts / m^2

2.1. EQUIPMENT: AIRCRAFT

All flights for the Kentucky Statewide '12 LiDAR project were accomplished through the use of customized Cessna 206's .These aircraft provided an ideal, stable aerial base for LiDAR acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Leica and Optech LiDAR systems.

2.2. LIDAR SENSOR

Photo Science utilized an Leica LiDAR sensor, serial number 93 and an Optec LiDAR sensor, serial number 247, during the project. Both systems are capable of collecting data at a maximum frequency of 500 kHz, which affords elevation data collection of up to 500,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). Both sensors are also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. The intensity of the first four returns is also captured during aerial acquisition.

Figure 5. Leica ALS70 LiDAR System

Figure 8. Optech Gemini LiDAR System

2.3. BASE STATION INFORMATION

GPS base stations were utilized during all phases of flight. Base stations at airports or known location within approximately 20 miles of the collection area were occupied with a Trimble Receiver and a Trimble Zephyr Geodetic Antenna during airborne operations of the project. Base station locations were verified using NGS OPUS service and subsequent surveys.

2.4. TIME PERIOD

Project specific flights were conducted over 49 days:

- 20111208
- 20111210
- 20111212
- 20120110
- 20120115
- 20120203
- 20120212
- 20120213
- 20120217
- 20120218
- 20120220
- 20120221
- 20120223
- 20120226
- 20120227
- 20122028
- 20120229
- 20120301
- 20120302
- 20120306
- 20120309
- 20120310
- 20120311
- 20120312
- 20120319
- 20120320
- 20120321
- 20120322
- 20120326
- 20120327
- 20120328
- 20120329
- 20120330
- 20120401
- 20120402
- 20120403
- 20120406
- 20120407
- 20121117
- 20121118

- 20121129
- 20121130
- 20121201
- 20121205
- 20121206
- 20121212
- 20121213
- 20121214
- 20121219
- 20130119
- 20130221

3. PROCESSING SUMMARY

3.1. INITIAL PROCESSING

Applanix + POSPac Mobile Mapping Suite software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the LiDAR sensor during all flights. POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory" (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the LiDAR missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory.

The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Point clouds were created using Optech DASHMap Post Processor software, or Leica ALS Post Processor software. GeoCue distributive processing software was used in the creation of some files needed in downstream processing, as well as in the tiling of the dataset into more manageable file sizes. TerraMatch is used to perform an assessment of the system offsets for pitch, roll, heading and scale, and the subsequent removal of these systematic biases. The data is now ready for analysis, classification, and filtering to generate a bare earth surface model in which the above-ground features are removed from the data set. TerraScan and TerraModeler software packages were then used for the automated data classification, manual cleanup, and bare earth generation. Project specific macros were developed to classify the ground and remove side overlap between parallel flight lines.

3.2. LAS CLASSIFICATION SCHEME

The classification classes are determined by the USGS Version 1.0 specifications and are an industry standard for the classification of LIDAR point clouds. All data starts the process as Class 1 (Unclassified),
and then through automated classification routines, classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

- Class 1 – Processed, but Unclassified – These points would be the catch all for points that do not fit any of the other deliverable classes. This would cover things like vegetation, buildings, cars, bridges, etc.
- Class 2 – Bare earth ground – This is the bare earth surface

- Class 7 – Noise – Low or high points, manually identified above or below the surface that could be noise points in point cloud.
- Class 9 – In-land Water – Points found inside of inland lake/ponds
- Class 10 – Ignored Ground – Points found to be close to breakline features. Points are typically moved to this class from class 2. This class is ignored during the DEM creation.
- Class 11 – Withheld – Points found to be noise during automated processing.
- Class 17 – Overlap Default (Unclassified) – Points found in the overlap between flight lines. These points are created through automated processing methods and not cleaned up during processing.
- Class 18 – Overlap Bare-earth ground – Points found in the overlap between flight lines. These points are created through automated processing, matching the specifications determined during the automated process, that are close to the Class 2 dataset (when analyzed using height from ground analysis)
- Class 25 – Overlap Water – Points found in the overlap between flight lines that are also located inside of hydro breaklines.

3.3. CLASSIFIED LAS PROCESSING

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) LiDAR data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 10). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes. The overlap data was classified to Class 17 (Overlap Default) and Class 18 (Overlap Ground). These classes were created through automated processes only and were not verified for classification accuracy.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. QT Modeler was used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. Photo Science proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information

3.4. HYDRO FLATTENING BREAKLINE PROCESS

Class 2 LiDAR was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of inland streams and rivers with a 50 foot nominal width and Inland Ponds and Lakes of 2 acres or greater surface area.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Stream and River Islands, using TerraModeler functionality.

Elevation values were assigned to all Inland streams and rivers using Photo Science proprietary software.

All ground (ASPRS Class 2) LiDAR data inside of the collected inland breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The breakline files were then translated to ESRI Shapefile/File GeoDatabase format using ESRI conversion tools.

3.5. RASTER DEM PROCESSING

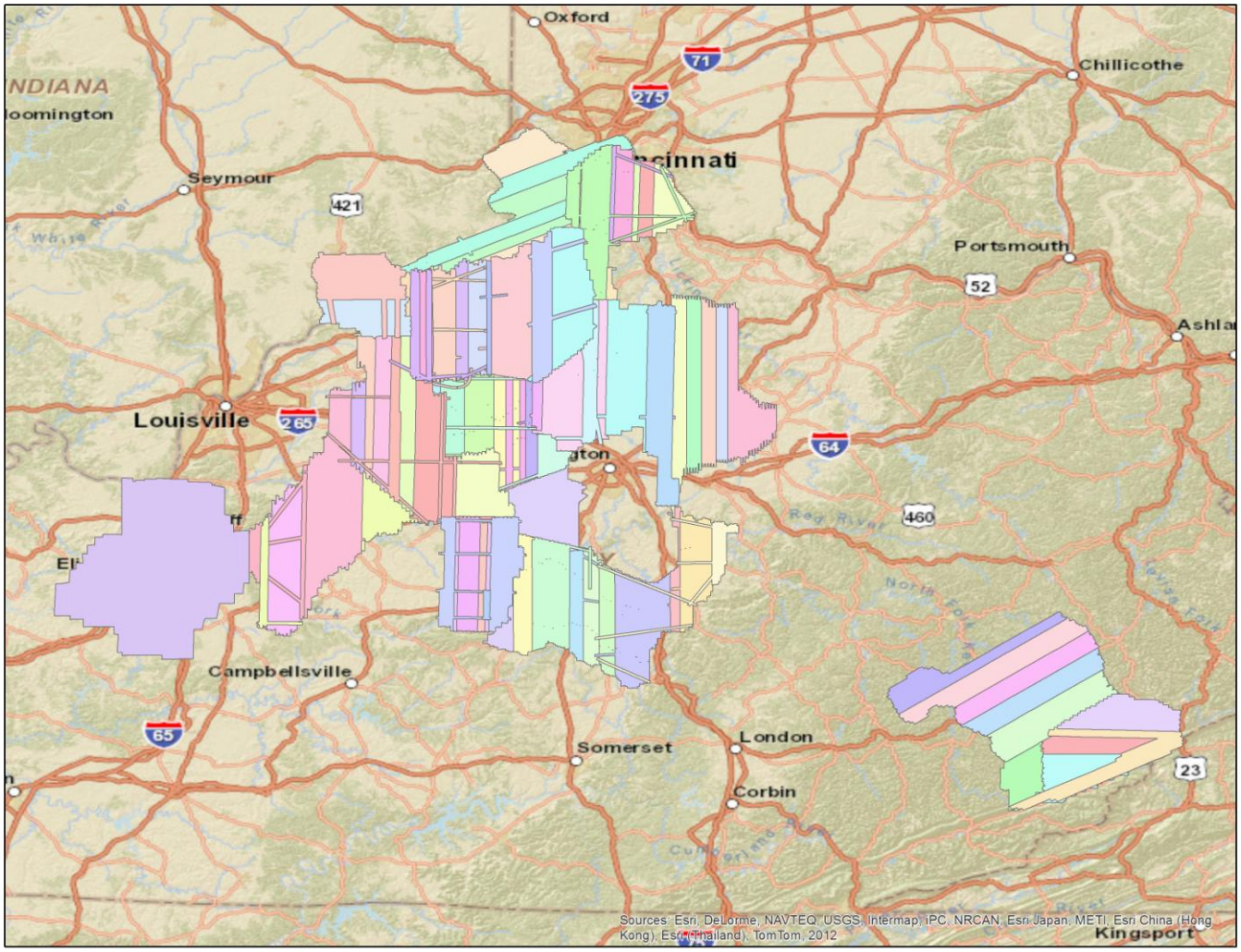
Using automated scripting routines within ArcMap, the ground (ASPRS Class 2) was combined with the Hydro Flattened Breaklines to create the 5.0 foot DEM.

ERDAS IMG files were created and a final check of the surface model was reviewed to verify that all closed water bodies were properly flattened, and all double line drains were monotonic.

4. PROJECT COVERAGE VERIFICATION

The Kentucky Statewide '12 project area coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generated project shape files depicting boundaries of specified project areas. The project area has 100% .LAS coverage.

Figure 7. LAS File Coverage: Overview



5. GROUND CONTROL AND CHECK POINT COLLECTION

Photo Science completed a GPS survey of variously selected ground control points for LiDAR accuracy validation. Figure 8 shows control point locations across project area. Table 3 depicts the Final Control Report as computed in TerraScan as a quality assurance check.

Figure 8. Control Point Locations

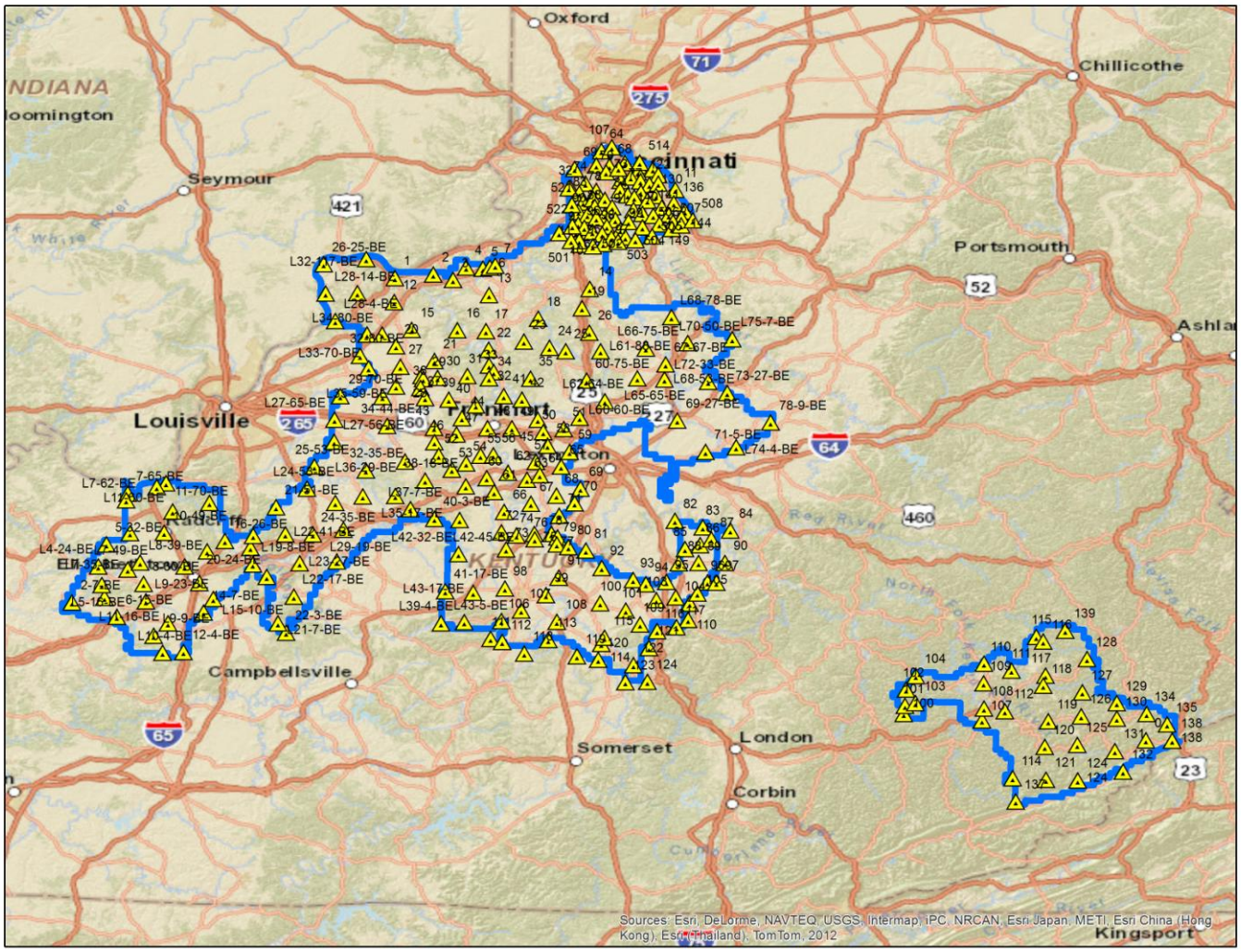


Table 3. Final Control Report (units = feet)
L:\7145-002\Ground_Control\Control_PA1.ctl

Number	Easting	Northing	Known Z	Laser Z	Dz
20-24-BE	4959195.07	3775953.28	463.63	463.44	-0.19
1	5078550.03	4133075.94	527.11	527.02	-0.09
2	5114407.85	4137394.90	776.25	776.48	0.23
3	5132918.18	4130781.01	711.34	711.75	0.41
4	5145129.60	4146023.06	681.81	681.16	-0.65
5	5160870.49	4144470.34	754.56	754.45	-0.11
6	5167034.52	4146018.89	835.04	835.14	0.10
7	5172220.39	4148591.02	867.24	867.27	0.03
9	5231661.58	4187697.78	896.43	896.21	-0.22
10	5251840.21	4187977.65	931.36	931.50	0.14
11	5339007.90	4240958.00	516.25	516.22	-0.03
11	5251265.06	4174370.64	911.13	911.19	0.06
12	5078200.36	4104420.92	839.35	838.56	-0.79
13	5166747.15	4113144.74	894.27	894.41	0.14
14	5260916.63	4121719.61	972.12	971.91	-0.21
15	5094749.40	4071171.35	838.60	838.22	-0.38
16	5137483.90	4071057.83	496.32	496.93	0.61
17	5164201.42	4070152.13	858.19	858.55	0.36
18	5212957.25	4085436.41	721.29	721.39	0.10
19	5253962.64	4098315.89	930.32	930.29	-0.03
20	5080040.80	4051477.54	922.20	921.92	-0.28
21	5116329.54	4034212.57	891.11	891.24	0.13
22	5166971.94	4048057.77	504.45	504.24	-0.21
23	5199893.66	4058089.73	945.11	945.03	-0.08
24	5224139.18	4050880.18	889.20	889.03	-0.17
25	5239150.46	4047065.80	774.69	774.63	-0.06
26	5261352.20	4069652.09	967.98	967.92	-0.06
27	5084183.17	4027350.21	886.95	887.02	0.07
28	5104489.41	4016266.89	880.45	880.40	-0.05
29	5106033.69	4012684.50	886.29	886.40	0.11
30	5119458.22	4013867.80	863.23	863.61	0.38
31	5147256.75	4016667.78	855.48	855.16	-0.32
32	5241371.00	4242106.99	906.66	906.40	-0.26
32	5167392.81	4029071.41	466.25	466.18	-0.07
33	5171965.91	4021366.87	494.28	494.14	-0.14
34	5167718.61	4013781.60	551.78	551.92	0.14
35	5206493.49	4013981.23	711.02	710.78	-0.24
36	5103313.03	4002008.23	889.32	889.35	0.03
37	5107840.58	3989766.28	906.29	906.15	-0.14
39	5129974.62	3988040.33	828.50	828.81	0.31
40	5155684.85	3981437.41	694.47	694.60	0.13
41	5181797.78	3992961.64	743.42	743.43	0.01
42	5198719.20	3988677.93	708.45	708.12	-0.33
43	5116468.93	3954363.12	903.68	903.42	-0.26
44	5142638.08	3965936.59	623.39	623.30	-0.09
45	5214058.67	3965171.74	853.69	853.63	-0.06
46	5117124.44	3937276.05	906.01	905.59	-0.42
47	5137579.57	3946653.07	748.83	748.98	0.15

Number	Easting	Northing	Known Z	Laser Z	Dz
48	5166949.24	3954493.34	741.42	741.45	0.03
49	5189633.57	3954423.61	803.51	803.69	0.18
50	5219282.09	3950314.70	834.21	833.96	-0.25
51	5238753.09	3954130.58	831.39	831.32	-0.07
52	5121031.19	3920947.23	912.81	912.71	-0.10
53	5133765.27	3904628.43	910.68	910.07	-0.61
54	5147099.53	3912278.92	913.09	912.33	-0.76
55	5160410.13	3921728.35	791.24	791.12	-0.12
56	5172477.65	3922143.92	810.85	810.54	-0.31
57	5212698.97	3914590.99	882.14	881.76	-0.38
58	5223561.64	3934210.54	858.65	858.47	-0.18
59	5244324.24	3927188.68	815.45	815.37	-0.08
60	5166460.75	3894661.96	802.36	801.82	-0.54
61	5173567.13	3878405.85	800.96	800.63	-0.33
62	5246607.41	4187301.93	930.53	930.47	-0.06
62	5186551.11	3901281.74	800.30	800.00	-0.30
63	5204770.82	3893257.29	868.88	868.59	-0.29
64	5269449.38	4286409.78	510.17	510.44	0.27
64	5216745.96	3898814.85	883.50	883.43	-0.07
65	5236687.97	3909163.50	929.67	929.57	-0.10
66	5183455.65	3854933.34	712.25	712.02	-0.23
67	5265251.63	4269114.29	600.33	600.33	0.00
67	5208653.63	3864655.18	845.64	845.42	-0.22
68	5277346.04	4268467.87	531.56	531.65	0.09
68	5232411.95	3874640.79	841.51	841.30	-0.21
69	5245023.76	4264514.28	880.61	880.73	0.12
69	5255209.92	3883225.20	976.71	976.83	0.12
70	5274240.77	4260706.45	845.72	845.78	0.06
70	5249987.11	3865827.62	977.34	977.27	-0.07
71	5235513.71	3850739.79	911.25	911.43	0.18
72	5181079.48	3830158.36	856.88	856.98	0.10
73	5288181.07	4250705.91	541.98	542.19	0.21
73	5185746.52	3810017.39	898.39	898.36	-0.03
74	5255402.81	4247255.42	877.73	878.09	0.36
74	5195362.83	3826720.60	851.73	851.65	-0.08
75	5212330.95	3828911.13	846.37	846.29	-0.08
76	5265672.09	4238758.92	863.33	863.35	0.02
76	5212823.10	3822055.05	922.11	922.12	0.01
77	5287353.43	4239723.11	874.46	874.38	-0.08
77	5228467.51	3828888.51	941.39	941.52	0.13
78	5249610.87	4235586.48	806.05	805.79	-0.26
78	5234425.77	3824815.76	864.47	864.35	-0.12
79	5233698.18	3816662.28	891.17	891.29	0.12
80	5244755.75	3813183.65	851.94	851.91	-0.03
81	5261137.75	3809354.32	831.66	831.78	0.12
82	5253260.87	4224505.31	810.62	810.66	0.04
82	5344760.35	3846024.29	590.96	590.89	-0.07
83	5262768.58	4228853.96	891.50	891.29	-0.21
83	5371438.33	3838669.90	732.94	733.00	0.06
84	5273657.12	4228177.29	920.29	920.18	-0.11
84	5397588.79	3835417.25	858.59	858.76	0.17

Number	Easting	Northing	Known Z	Laser Z	Dz
85	5264418.37	4219753.12	932.52	932.27	-0.25
85	5354883.69	3812724.44	817.68	817.66	-0.02
86	5280559.17	4219504.77	855.17	854.99	-0.18
86	5369336.23	3817542.85	894.09	894.03	-0.06
87	5379808.15	3824589.11	868.60	868.60	0.00
88	5249337.28	4213392.78	954.36	954.23	-0.13
88	5349486.02	3795585.69	900.76	900.96	0.20
89	5368165.74	3796159.68	915.12	915.18	0.06
90	5257665.94	4209662.47	879.64	879.44	-0.20
90	5393142.85	3796741.70	906.04	905.99	-0.05
91	5274015.16	4209419.83	877.62	877.83	0.21
91	5236009.42	3776969.14	909.58	909.52	-0.06
92	5265832.27	4205648.71	883.17	883.21	0.04
92	5276362.37	3788905.15	938.34	938.38	0.04
93	5306491.61	3774938.03	995.51	995.56	0.05
94	5283552.09	4204381.75	869.22	869.04	-0.18
94	5318737.88	3769967.15	854.05	853.96	-0.09
95	5249191.17	4198049.11	910.79	910.71	-0.08
95	5337880.14	3772890.26	1011.22	1011.67	0.45
96	5255006.36	4194321.38	901.20	900.91	-0.29
96	5376986.99	3773168.11	934.40	934.31	-0.09
97	5275671.64	4196280.00	863.33	862.82	-0.51
97	5385380.58	3773085.19	945.77	945.85	0.08
98	5262394.44	4189485.26	904.18	904.04	-0.14
98	5184911.65	3763344.61	974.88	975.15	0.27
99	5288553.55	4192208.22	537.38	537.27	-0.11
99	5223860.79	3756110.85	946.81	946.93	0.12
100	5271506.41	4187079.11	873.84	873.85	0.01
100	5275542.49	3746654.40	1027.72	1027.94	0.22
101	5299773.31	3738547.63	995.89	995.82	-0.07
102	5250441.46	4178768.18	926.55	926.42	-0.13
102	5328712.33	3751143.91	1027.80	1027.71	-0.09
103	5280280.50	4182396.60	854.83	855.02	0.19
103	5347275.98	3754635.48	913.70	913.77	0.07
104	5293320.08	4183429.18	822.91	822.61	-0.30
104	5360368.60	3747826.60	1038.68	1038.76	0.08
105	5272819.87	4175457.18	858.46	858.56	0.10
105	5367610.84	3759566.00	1020.41	1020.41	0.00
106	5182053.54	3724565.02	1091.03	1091.06	0.03
107	5279072.62	4291047.36	505.18	505.37	0.19
107	5200600.84	3736955.35	987.83	987.92	0.09
108	5234593.46	3724160.16	992.45	992.57	0.12
109	5313737.65	3721744.24	1049.96	1049.93	-0.03
110	5359129.75	3728266.50	999.19	999.06	-0.13
111	5291612.94	4272054.26	830.09	830.49	0.40
111	5171867.54	3703090.89	1398.23	1398.32	0.09
112	5304110.45	4268971.96	497.75	498.28	0.53
112	5183166.06	3699372.49	1050.12	1050.21	0.09
113	5285860.08	4265770.98	842.29	842.45	0.16
113	5226674.89	3702367.15	1328.85	1328.93	0.08
114	5317711.27	4265132.63	498.81	498.84	0.03

Number	Easting	Northing	Known Z	Laser Z	Dz
114	5277397.22	3698186.30	881.89	882.02	0.13
115	5280334.37	3705565.58	870.44	870.57	0.13
116	5303824.10	4261288.75	818.75	818.69	-0.06
116	5329925.97	3714476.27	1063.50	1063.42	-0.08
117	5348466.37	3719165.33	1071.15	1071.30	0.15
118	5297525.35	4255202.60	785.51	785.10	-0.41
118	5204247.13	3686022.25	1094.71	1094.76	0.05
119	5254408.87	3683425.67	1280.59	1280.72	0.13
120	5322808.36	4258502.76	833.03	833.20	0.17
120	5274612.20	3679323.80	982.48	981.88	-0.60
121	5322826.01	3694005.07	1260.69	1260.72	0.03
122	5306546.92	4250534.71	703.39	703.60	0.21
122	5308106.93	3673605.22	961.27	961.24	-0.03
123	5300649.30	3652777.18	1204.40	1204.43	0.03
124	5314735.02	4246790.82	623.80	623.73	-0.07
124	5321800.89	3653841.45	1200.67	1200.67	0.00
125	5323062.28	4247995.91	705.64	705.75	0.11
127	5307129.26	4237260.44	818.56	818.67	0.11
128	5294843.18	4233642.56	854.47	854.67	0.20
129	5301016.03	4231114.65	638.08	638.10	0.02
130	5321172.97	4233143.84	540.27	540.23	-0.04
132	5240038.72	4241457.24	880.54	880.28	-0.26
133	5313286.31	4227592.22	653.00	653.05	0.05
135	5326885.79	4219602.54	769.17	769.64	0.47
136	5337996.70	4224814.94	778.99	779.01	0.02
137	5300445.53	4216526.35	822.52	822.60	0.08
140	5308886.32	4211799.53	679.14	679.35	0.21
141	5348597.53	4215301.40	521.82	522.48	0.66
142	5318922.01	4209606.26	833.90	833.36	-0.54
143	5333388.27	4210193.46	863.01	863.13	0.12
144	5345276.52	4207595.19	616.01	616.05	0.04
145	5296147.20	4201993.37	807.44	807.47	0.03
148	5337447.47	4202340.39	923.84	923.92	0.08
149	5325012.83	4199679.74	859.26	859.42	0.16
151	5308987.10	4195559.02	766.72	766.51	-0.21
501	5242964.80	4178852.93	904.39	904.11	-0.28
502	5263084.54	4172667.89	906.85	906.81	-0.04
503	5286447.21	4178414.51	624.12	623.96	-0.16
504	5302611.00	4180462.68	579.58	579.73	0.15
505	5318185.33	4185452.07	603.24	603.21	-0.03
506	5336633.70	4194287.22	897.86	897.91	0.05
507	5345090.91	4198601.78	715.87	715.82	-0.05
508	5355843.55	4204671.34	518.41	518.59	0.18
514	5305564.56	4272988.79	490.19	489.78	-0.41
521	5242828.35	4221645.11	910.05	910.01	-0.04
522	5243796.67	4196100.32	781.06	781.23	0.17
21-51-BE	4967998.64	3859228.39	679.66	679.50	-0.16
22-3-BE	4977928.07	3709648.86	902.86	902.97	0.11
24-35-BE	5002695.61	3826767.55	711.12	710.94	-0.18
25-53-BE	5004019.96	3907581.77	664.05	664.38	0.33
26-25-BE	5011843.54	4149169.50	491.23	491.17	-0.06

Number	Easting	Northing	Known Z	Laser Z	Dz
29-70-BE	5027960.97	3991758.77	785.22	785.06	-0.16
32-104-BE	5043407.27	4114501.71	905.93	905.89	-0.04
32-35-BE	5052734.16	3903366.37	733.99	733.96	-0.03
32-80-BE	5046286.30	4040009.53	834.04	833.87	-0.17
34-44-BE	5072295.17	3956512.65	752.56	752.61	0.05
38-18-BE	5108374.77	3891649.70	823.46	823.54	0.08
40-3-BE	5117536.25	3845977.44	836.35	836.37	0.02
41-17-BE	5128643.28	3759658.61	930.71	930.88	0.17
60-75-BE	5259447.93	4012040.81	982.75	983.08	0.33
67-67-BE	5333290.04	4032433.02	802.51	802.51	0.00
69-27-BE	5345263.54	3965616.44	827.18	827.72	0.54
71-5-BE	5372419.13	3928863.68	851.21	851.38	0.17
73-27-BE	5391575.02	3999579.29	877.12	877.34	0.22
78-9-BE	5433070.56	3964953.15	963.22	963.88	0.66
L18-17-BE	4943753.29	3810368.34	452.42	452.38	-0.04
L19-19-BE	4946279.10	3824993.22	489.87	489.79	-0.08
L19-8-BE	4946007.60	3790902.03	457.68	457.51	-0.17
L21-7-BE	4970161.12	3720337.01	523.86	523.82	-0.04
L22-17-BE	4984910.91	3752495.50	557.57	557.72	0.15
L22-41-BE	4976702.60	3826735.41	617.79	617.59	-0.20
L23-27-BE	4990383.62	3792345.05	644.17	644.13	-0.04
L24-53-BE	4997211.47	3881237.43	491.50	491.56	0.06
L27-56-BE	5022498.44	3937145.00	645.10	645.39	0.29
L27-65-BE	5022704.63	3963529.14	726.41	726.12	-0.29
L28-14-BE	5013934.06	4114081.74	792.77	792.93	0.16
L28-4-BE	5022973.04	4081527.27	786.49	786.49	0.00
L29-19-BE	5031800.65	3832273.91	771.02	771.00	-0.02
L29-29-BE	5023871.21	3864468.21	695.33	695.21	-0.12
L29-6ALT-BE	5025666.33	3794601.35	723.87	723.84	-0.03
L32-117-BE	5051757.91	4155185.44	486.95	486.93	-0.02
L32-25-BE	5049629.28	3872360.43	791.20	791.51	0.31
L32-88-BE	5052768.94	4065129.38	711.30	711.50	0.20
L33-70-BE	5054569.14	4025278.62	804.57	804.68	0.11
L34-55-BE	5067967.84	3991092.03	792.30	792.46	0.16
L34-80-BE	5066867.70	4065284.55	887.17	887.20	0.03
L35-17-BE	5080489.04	3872776.20	631.53	631.67	0.14
L35-59-BE	5080589.89	4003584.55	846.53	846.42	-0.11
L36-29-BE	5089474.58	3914238.67	831.12	831.22	0.10
L37-7-BE	5094793.54	3857211.88	802.86	802.94	0.08
L39-4-BE	5124630.16	3721319.86	765.98	766.23	0.25
L42-32-BE	5140497.64	3804003.12	886.32	886.15	-0.17
L42-45-BE	5141330.11	3844646.64	854.60	854.45	-0.15
L43-17-BE	5154823.30	3758031.16	858.73	858.88	0.15
L43-58-BE	5146943.40	3885010.73	780.91	780.67	-0.24
L43-5-BE	5146699.93	3722622.01	937.94	937.71	-0.23
L60-60-BE	5253380.60	3967855.26	835.18	834.99	-0.19
L61-88-BE	5271939.80	4047228.93	998.34	998.61	0.27
L62-64-BE	5276837.75	3987911.76	917.51	917.73	0.22
L65-65-BE	5306943.12	4015610.46	800.77	800.80	0.03
L66-75-BE	5314530.40	4051244.65	819.16	819.73	0.57
L68-53-BE	5332491.20	4014471.74	754.31	754.31	0.00

Number	Easting	Northing	Known Z	Laser Z	Dz
L68-78-BE	5337997.19	4089003.43	898.77	898.86	0.09
L70-50-BE	5353476.73	4058143.66	901.20	900.90	-0.30
L72-33-BE	5373414.57	4012625.90	850.81	850.55	-0.26
L74-4-BE	5401070.00	3934695.18	1001.32	1001.35	0.03
L75-7-BE	5395138.76	4063758.22	714.24	714.74	0.50
10-49-BE	4862202.450	3828515.44	776.78	776.78	0
11-70-BE	4864139.540	3887481.6	434.82	434.73	-0.09
12-4-BE	4880339.090	3686457.45	749.73	749.74	0.01
14-7-BE	4899280.360	3733291.95	674.88	674.95	0.07
16-26-BE	4919647.070	3818825.29	444.55	444.72	0.17
2-7-BE	4774616.610	3745885.84	539.91	539.83	-0.08
5-32-BE	4807555.120	3814831.86	705.77	705.96	0.19
6-15-BE	4817104.250	3728533.71	737.34	737.22	-0.12
7-65-BE	4827885.290	3875444.13	664.84	665.03	0.19
8-30-BE	4842501.450	3767905.4	729.34	729.47	0.13
L10-4-BE	4860402.780	3685438.76	713.83	713.87	0.04
L10-67-BE	4855253.660	3883134.96	430.87	430.85	-0.02
L11-16-BE	4865622.410	3720735.46	703.3	703.25	-0.05
L11-60-BE	4870372.890	3853762.65	690.83	690.88	0.05
L12-38-BE	4881567.400	3788495.1	807.32	807.14	-0.18
L14-18-BE	4895287.680	3768359.98	778.85	778.61	-0.24
L14-31-BE	4902624.440	3806287.43	834.47	834.44	-0.03
L15-10-BE	4908664.470	3749488.78	776.54	776.52	-0.02
L15-46-BE	4904916.820	3864210.74	451.07	451.05	-0.02
L4-24-BE	4799533.820	3788867.78	907.88	907.95	0.07
L5-11-BE	4805593.840	3751124.55	821.53	821.58	0.05
L5-16-BE	4802947.120	3766472.52	798.13	798.31	0.18
L7-35-BE	4827616.340	3784673.15	728.61	729	0.39
L7-49-BE	4830062.700	3828058.26	789.51	789.78	0.27
L7-62-BE	4826228.180	3867390.41	659.46	659.56	0.1
L8-39-BE	4839226.860	3793338.81	827.48	827.73	0.25
L9-23-BE	4844882.020	3746995.85	737.12	737.2	0.08
L9-9-BE	4851784.960	3705942.71	672.84	672.78	-0.06

Average dz	**-0.001 ft**
Minimum dz	**-0.790 ft**
Maximum dz	**+0.660 ft**
Root Mean Square	**0.217 ft**
Std Deviation	**0.218 ft**

Table 4. Final Control Report (units = feet)
L:\7145-002\Ground_Control\Control_PA2.ctl

Number	Easting	Northing	Known Z	Laser Z	Dz
100	5566665.14	3620228.94	944.97	944.75	-0.22
101	5567673.15	3629823.94	1273.25	1273.21	-0.04
102	5568316.93	3649048.57	890.98	891.06	0.08
103	5577536.74	3633094.89	954.07	953.89	-0.18
104	5577161.67	3665853.64	840.10	840.19	0.09
107	5641342.41	3614279.68	971.49	971.49	0.00
108	5643024.88	3628668.68	1055.97	1056.22	0.25
109	5641774.12	3658619.78	991.40	991.41	0.01
110	5641270.85	3681972.71	835.31	835.49	0.18
111	5667656.13	3674543.46	834.41	834.55	0.14
112	5662961.74	3626041.08	1052.53	1052.67	0.14
115	5690218.26	3715397.26	912.32	911.81	-0.51
116	5697112.72	3709760.06	920.27	920.03	-0.24
117	5700539.89	3669426.13	1078.61	1078.50	-0.11
118	5698388.55	3657235.96	981.80	981.50	-0.30
119	5704637.46	3614823.36	939.18	939.26	0.08
124	5734642.78	3545347.80	1156.04	1156.04	0.00
126	5735866.53	3622124.45	1037.51	1037.43	-0.08
127	5736133.54	3650415.42	1067.62	1067.67	0.05
128	5739396.48	3690237.83	1481.08	1481.40	0.32
129	5769098.58	3638536.49	1270.10	1270.32	0.22
130	5769685.80	3620004.34	1174.34	1174.48	0.14
132	5777649.40	3557263.56	1627.42	1627.35	-0.07
134	5797879.20	3626656.02	1393.32	1393.26	-0.06
135	5817992.75	3614702.44	1449.20	1449.13	-0.07
138	5823579.30	3595779.83	1887.65	1887.50	-0.15
139	5717581.34	3723526.11	1139.30	1139.42	0.12
124	5734642.78	3545347.80	1156.04	1156.62	0.58
125	5733088.79	3587769.75	1007.58	1007.35	-0.23
131	5769241.08	3581398.76	1141.60	1141.61	0.01
138	5823579.30	3595779.83	1887.65	1887.63	-0.02
133ALT	5798291.89	3595229.02	1251.50	1251.18	-0.32
114	5672551.21	3546336.11	1553.56	1553.58	0.02
120	5701958.18	3584237.48	992.23	992.72	0.49
121	5704486.78	3545242.99	1612.66	1612.37	-0.29
137	5676186.96	3518463.93	1840.17	1839.95	-0.22

Average dz	**-0.005 ft**
Minimum dz	**-0.510 ft**
Maximum dz	**+0.580 ft**
Root Mean Square	**0.221 ft**
Std Deviation	**0.224 ft**