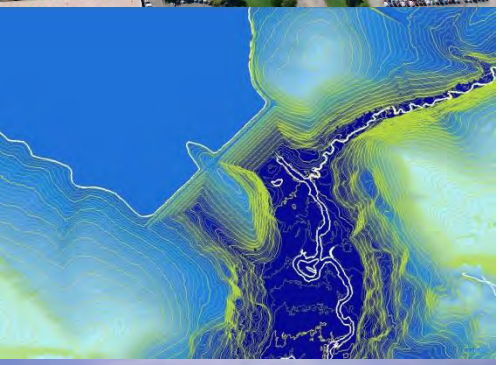
High Density Aerial Lidar Applications

Matt Vinopal, CP, CMS, GISP

AYRES ASSOCIATES

2019 Fall SE MN GIS Users Group Meeting

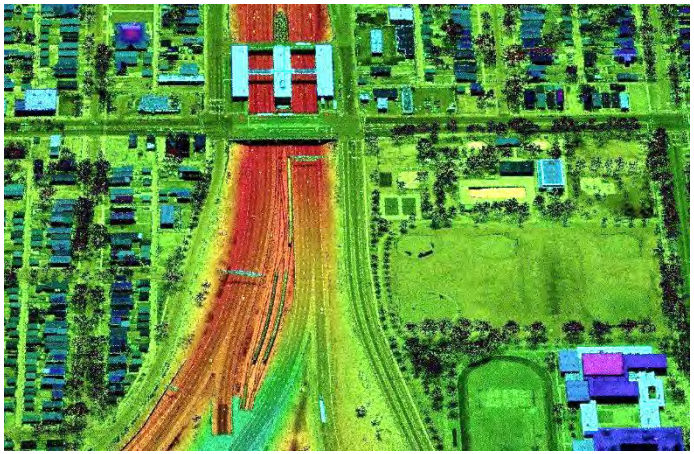


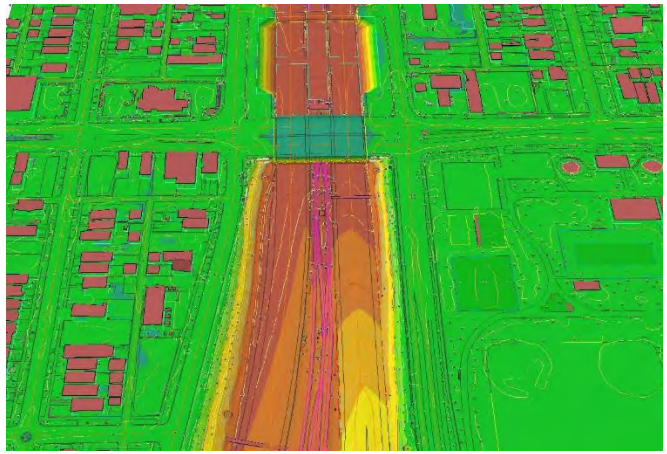
AYRES ASSOCIATES

Architecture • Civil/Municipal Engineering • Construction Services • Environmental • Geospatial Services • Landscape Architecture • Planning • Structural Design & Inspection • Subsurface Utility Engineering • Traffic Engineering • Transportation Engineering • Water Resources

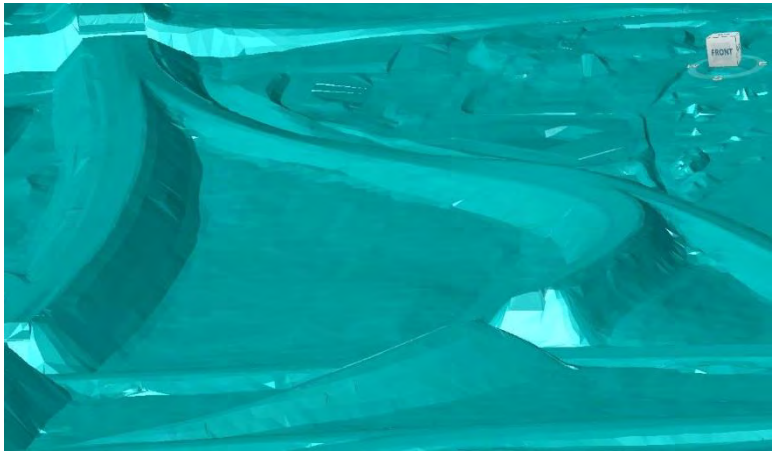
Geospatial Division

- ✓ Aerial imagery
- ✓ Photogrammetry
- ✓ Aerial LiDAR
- ✓ Mobile LiDAR
- ✓ HD laser scanning
- ✓ GIS consulting
- ✓ Boundary survey
- ✓ Construction staking
- ✓ Hydrographic survey
- ✓ Right-of-way plats
- ✓ Ground control
- ✓ Geodetic control



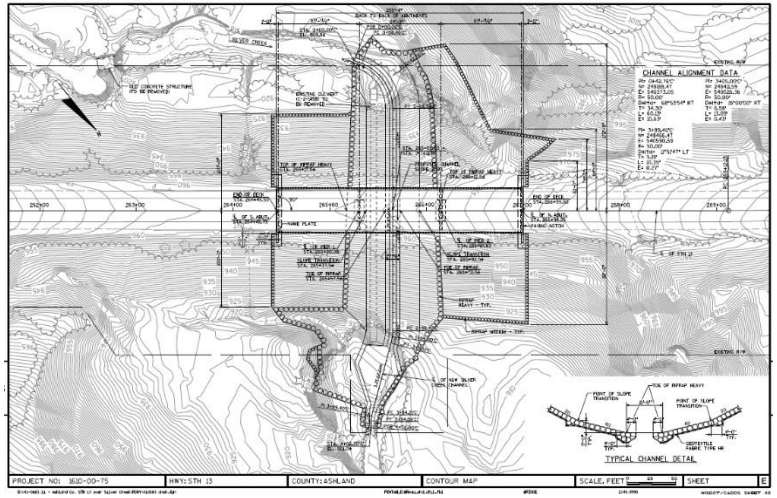


Transportation Applications for Lidar



Roadway Design:

- ✓ Pre-design/conceptual design
- ✓ Supplemental dtm *(photogrammetry, mobile lidar, etc.)*



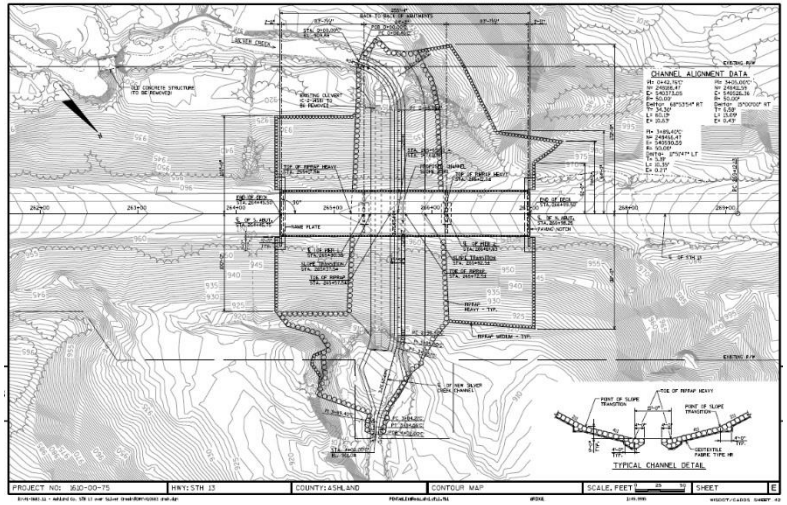
Hydraulic Design:

- ✓ Culvert sizing- based on slope and distance traveled
- ✓ analyze the overall watershed
- ✓ size existing ditches to ensure proposed drainage is equal or larger
- ✓ determine existing slopes and the time of concentration (how fast water is expected to flow across land)

Transportation Applications for Lidar

Recovery:

- ✓ Emergency repairs
- ✓ Earthwork calculations
- ✓ Expedited estimates and plans



Asset Management:

- ✓ Obstructions and clearances
- ✓ Feature extraction
- ✓ Maintenance

Definitions

Point Cloud – dataset of XYZ points collected from a LiDAR sensor

LAS – the most common format for storing lidar point cloud data

Returns – each pulse from the laser sensor can have multiple returns

PPM – refers to the density of lidar data, Points Per Meter (square)

NPS – refers to the point spacing of lidar data, Nominal Point Spacing

QL2 LiDAR – Quality Level 2, which is the current USGS/FEMA spec for floodplain mapping

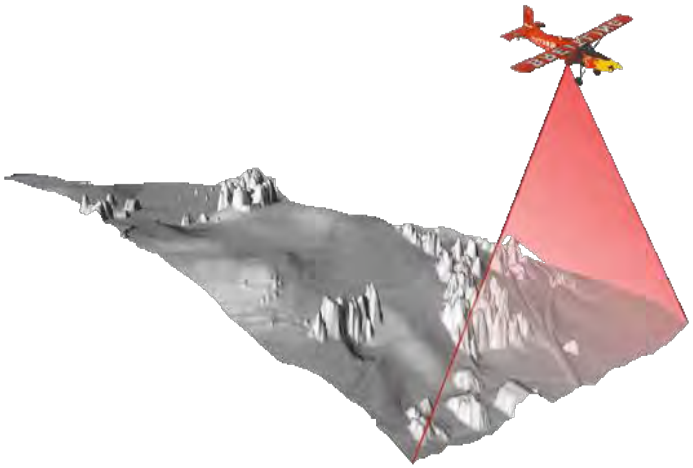
Model Key Point – A subset of ground points created by a thinning filter.

RMSEz - root-mean-square-difference in elevation

AYRES ASSOCIATES

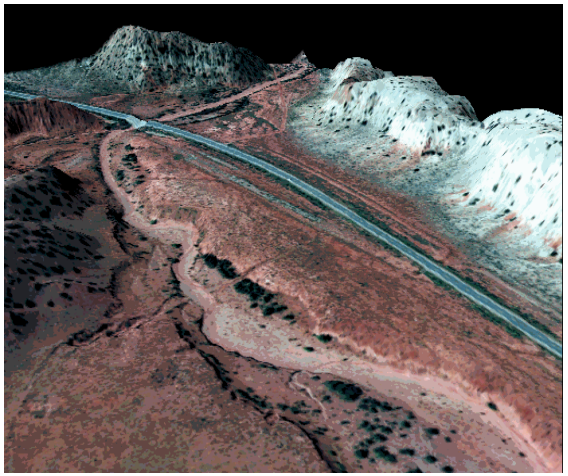
Airborne Lidar Technology

Major improvements in last 15 years



- Sensor technology
  - Fly higher
  - Larger swath
- Higher number of returns per pulse
- Faster scan frequency
- Software advancements
- IT infrastructure

=



- Better vertical accuracy (2X)
- Better horizontal accuracy
- Improved point classification
- Better representation of terrain
- Better above ground modeling
- Greater feature extraction capability

Current Industry Specifications

USGS: Published Lidar Base Specification v1.2 in November 2014. Current Specification references Lidar Base Specification V2.1

ASPRS: Published Accuracy Standards for Digital Geospatial Data in November 2014

FEMA: Aligns with the USGS Lidar Guidelines and Base Specifications v13 in July 2010, adopts USGS Lidar Base Specification v1.2 in 2015.

USACE: Photogrammetric and lidar mapping manual and ASPRS Positional guidelines for Digital Geospatial Data in November 2014.

AYRES ASSOCIATES

Vertical Accuracy Specifications

	Quality Level 2 (QL2)	Quality Level 0 (QL0+)
Point Density	≥2.0	≥30.0
Vertical Accuracy	10cm RMSE non-vegetated 30cm at 95th percentile vegetated	5cm RMSE non-vegetated 15cm at 95th percentile vegetated
DEM Cell Size	2ft	1ft
Contour Interval	1 or 2 – foot	1- foot

Vertical Accuracy Analysis

Calibration Control

- Non-vegetated, open areas

Checkpoint Control

- Non-vegetated Vertical Accuracy
  - Bare Earth
  - Urban
- Vegetated Vertical Accuracy
  - Swamp
  - Low Grass
  - Forest

Point: 400 Bare Earth

Survey X: 3045049.53, Survey Y: 1400599.15, Z1: 6155.87, Z DEM: 6155.86, Z LAS: 6155.89, LC Type: 1, ΔZ DEM: -0.01, ΔZ LAS: 0.03

North

South

East

West

AYRES ASSOCIATES

Vertical Accuracy Reporting

Project Information

Prepared By: Ayres Associates
Project Name: Larimer County, CO, North Fork of the Big Thompson River LiDAR Vertical Accuracy Report
Sensor Info: Optech Orion H300
Required Nominal Pulse Spacing: 0.7
Contractor Name: Ayres Associates
Units: US Survey Feet
Date of Acquisition: Start: 3/23/2017 Finish: 3/23/2017

LiDAR Accuracy Assessment Summary

Land Cover Type	# of Points	NVA	VVA
LAS		95% confidence level	N/A
1. Bare Earth	6	0.135	N/A
2. Urban Areas	5	0.138	N/A
3. Tall Weeds	2	N/A	0.299
5. Forest	7	N/A	0.406
TOTAL	**20**	N/A	N/A
DEM		95% confidence level	95th percentile
1. Bare Earth	6	0.191	N/A
2. Urban Areas	5	0.096	N/A
3. Tall Weeds	2	N/A	0.313
5. Forest	7	N/A	0.428
TOTAL	20	0.163	0.421

Units: US Survey Feet

AYRES ASSOCIATES

QL2 Approach

Medium Density Project Approach – Quality Level 2 (QL2)

QL2 Base Project:

- Acquire lidar data at 2ppsm for countywide topographic mapping
- Achieve vertical accuracy of 10cm RMSEz
- Adhere to newest USGS lidar base specifications v1.3 (used for 3DEP)
- Collect calibration ground control to meet vertical specs

QL2 Enhancement and Derivative Options:

- Vertical accuracy checkpoint collection and assessment
- Improved topographic datasets from the base project
- Higher definition hydro breaklines
- Additional above ground point classifications
- Bare earth specific datasets
- Feature extraction

QL0+ Approach

High Density Approach – Quality Level 0+ (QL0+)

QL0+ Base Project

- Acquire lidar data at 30 ppsm
- Achieve vertical accuracy of 5cm RMSEz
- Adhere to newest USGS lidar base specifications v1.3 (used for 3DEP)
- Collect calibration ground control to meet vertical specs

QL0+ Enhancement and Derivative Options (same as QL2 options, plus):

- 2D and/or 3D feature extraction
- Asset extraction (walls, edge of pavement, guardrails, paint lines, etc)
- Transportation corridor extraction (ribbons of point cloud data and surface)

Project Design Objectives

Accuracy objectives:

Example: Surface RMSE: < 0.15', calibration stat's: ~ 0.08'

Control:

~ 2pts per mile

off private land?

Wing points needed?

Technology:

Paired lidar/imaging vs. separate flights

Project Design Objectives

Contract Example 1:

The planimetric mapping and ortho-mosaic must meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 12cm (0.4ft) RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 30cm (1 foot) at a 95% confidence level.

The aerial LiDAR DTM product must meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 3cm (0.10ft) RMSEz Vertical Accuracy Class equating to Non-Vegetated Vertical Accuracy (NVA) =+/- 6cm (0.2ft) at 95% confidence level, and Vegetated Vertical Accuracy (VVA) of 15cm (0.50ft) RMSEz Vertical Accuracy Class equating to =+/- 30cm (1ft) at 95% confidence level.

Contract Example 2:

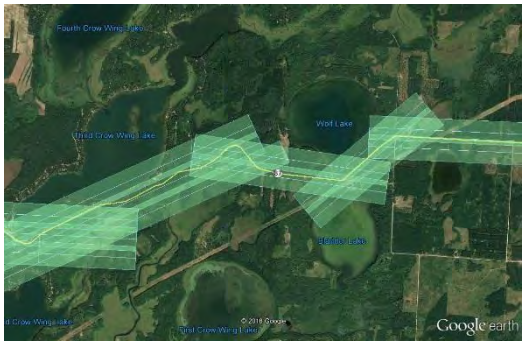
The aerial Lidar mission and processing will be performed to produce a surface model that achieves 3-5cm (0.10-0.16-ft) RMSE (Root Mean Square Error), or greater (using NSSDA procedures), on paved surfaces of the roadway when tested against independent survey check points. The bare earth surface on non-vegetated, non-paved surfaces will achieve 10cm (0.33-ft) RMSE.

AYRES ASSOCIATES

High Density Lidar Approach (>30 ppsm)

The Mission

1) Flight Planning – Lidar and imagery
2) Ground control layout and survey
3) Conduct flight(s)
4) Post-flight QA/QC



Check Points in Report	39		
Check Points with LiDAR Coverage	39		
Check Points (NVA)	39		
Check Points (VVA)	0		
Average Vertical Error Reported	0.008	U.S. Survey Foot	
Maximum (highest) Vertical Error I	0.206	U.S. Survey Foot	
Median Vertical Error Reported	0.003	U.S. Survey Foot	
Minimum (lowest) Vertical Error R	-0.074	U.S. Survey Foot	
Standard deviation of Vertical Erro	0.062	U.S. Survey Foot	
Skewness of Vertical Error	1.102		
Kurtosis of Vertical Error	1.422		
Non-vegetated Vertical Accuracy (	1.889	cm	PASS
Non-vegetated Vertical Accuracy (	3.703	cm	PASS
FGDC/NSSDA Vertical Accuracy at t	3.703	cm	
Non-vegetated Vertical Accuracy (	1.706	cm	PASS
Non-vegetated Vertical Accuracy (	3.343	cm	PASS

This data set was tested to meet A equating to +/- 3.703cm at the 95% confidence level.

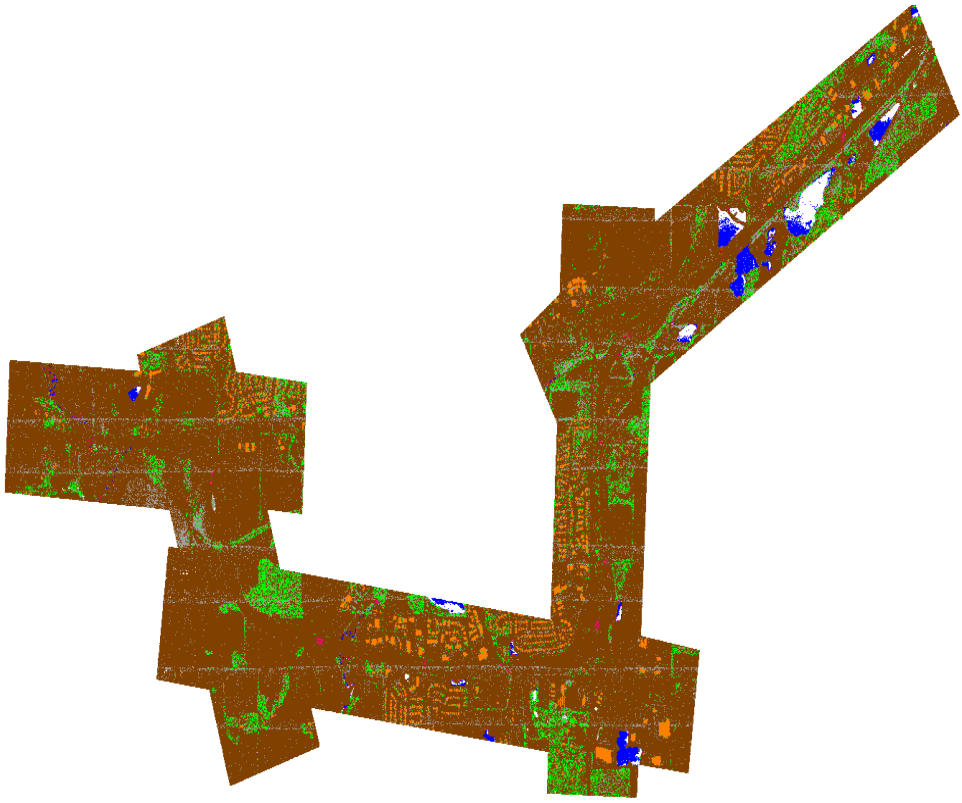
Check Point Id	Check Point X	Check Poi	Coverage	Check Point Z	Z from LiDAR	NVA or VVA	Z Error	Minimum Z	Median Z	Maximum Z	Intensity
150	1853655.925	798233.1	Yes	1123.938	1123.868		-0.07	1123.831	1123.861	1123.901	384
127	1876491.891	781102.4	Yes	1164.824	1164.769		-0.055	1164.751	1164.761	1164.771	557
112	1846026.482	804144.5	Yes	1096.356	1096.289		-0.067	1096.261	1096.291	1096.291	190
104	1819837.248	804896.4	Yes	1049.276	1049.202		-0.074	1049.201	1049.201	1049.221	420
125	1871841.919	784276.4	Yes	1152.638	1152.705		0.067	1152.641	1152.681	1152.751	582
128	1877069.95	781231.1	Yes	1165.982	1165.927		-0.055	1165.911	1165.941	1165.941	950
108	1832772.177	804221.6	Yes	1085.611	1085.554		-0.057	1085.541	1085.551	1085.571	372
116	1856312.415	796301.1	Yes	1136.08	1136.021		-0.059	1136.001	1136.021	1136.031	859
114	1846235.763	802968.2	Yes	1095.977	1095.918		-0.059	1095.911	1095.931	1095.941	1148
129	1877032.055	780103.3	Yes	1167.845	1167.801		-0.044	1167.801	1167.801	1167.811	543
119	1861540.245	792122	Yes	1137.846	1137.813		-0.033	1137.811	1137.811	1137.821	1851
115	1850246.788	800859.9	Yes	1108.083	1108.059		-0.024	1108.051	1108.051	1108.071	306
113	1845989.857	802508.9	Yes	1096.227	1096.196		-0.031	1096.191	1096.211	1096.211	1073
141	1897828.911	774067.7	Yes	1176.358	1176.328		-0.03	1176.311	1176.331	1176.341	1593
142	1902100.349	772428.9	Yes	1184.681	1184.684		0.003	1184.641	1184.681	1184.701	621
124	1873999.374	781614.5	Yes	1168.511	1168.476		-0.035	1168.471	1168.471	1168.491	377
137	1889353.068	776873.1	Yes	1171.314	1171.296		-0.018	1171.291	1171.291	1171.301	509
130	1879724.591	778882	Yes	1173.703	1173.671		-0.032	1173.671	1173.671	1173.671	3138

2-PPSM

Return	Point Count	%	Z Min	Z Max
All Returns	65,603,943	100.00	309.80	2964.32
Unknown	0	0.00	0.00	0.00
First	60,312,606	91.93	309.80	2964.32
Second	4,445,119	6.78	557.86	2473.11
Last	60,314,920	91.94	309.80	2964.32
Single	55,869,327	85.16	309.80	2964.32
First-of-Many	4,443,279	6.77	653.73	2791.98

Classification Codes

Classification	Point Count	%	Z Min	Z Max	Min Intensity	M
1 - Unclassified	7,069,944	10.78	920.98	1223.48	1	
2 - Ground	50,075,151	76.33	921.21	1135.35	1	
5 - High Vegetation	6,093,739	9.29	931.87	1224.56	1	
6 - Building	1,869,033	2.85	938.21	1113.76	1	
7 - Low Point (Noise)	7,181	0.01	309.80	1098.61	4	
9 - Water	413,631	0.63	920.88	1089.06	1	
10 - Ignored Ground	30,770	0.05	920.92	1090.11	4	
17 - Bridge	43,602	0.07	933.35	1053.69	1	
18 - High Point (Noise)	892	0.00	944.64	2964.32	1681	



30-PPSM

Metadata | Statistics | Histogram | Projection

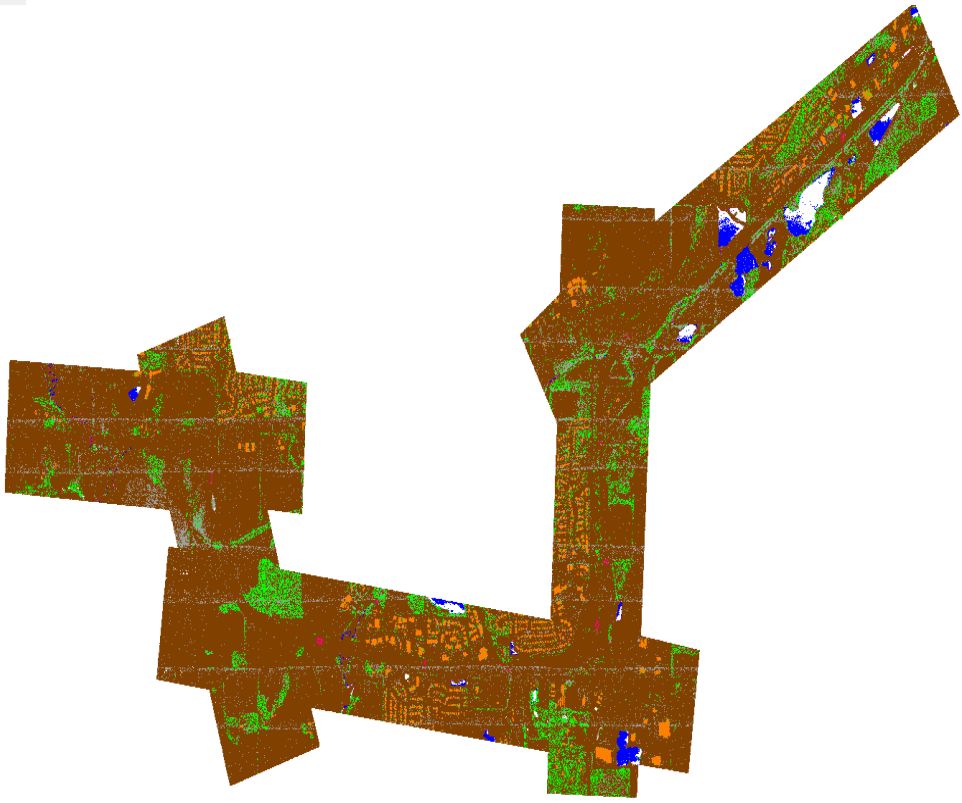
Returns

Return	Point Count	%	Z Min	Z Max
All Returns	615,266,012	100.00	602.28	1237.08
Unknown	0	0.00	0.00	0.00
First	536,970,644	87.27	729.96	1237.08
Second	58,543,497	9.52	602.28	1231.94
Last	536,975,611	87.28	602.28	1221.21
Single	478,430,076	77.76	729.96	1221.21
First-of-Many	58,540,568	9.51	922.83	1237.08

Attributes

Name	Min	Max
Return No.	1	5
Intensity	1	3710
Class Code	1	1
Scan Angle	-12.00	11.00
User Data	0	0
Point Source	111	2011

Classification Codes



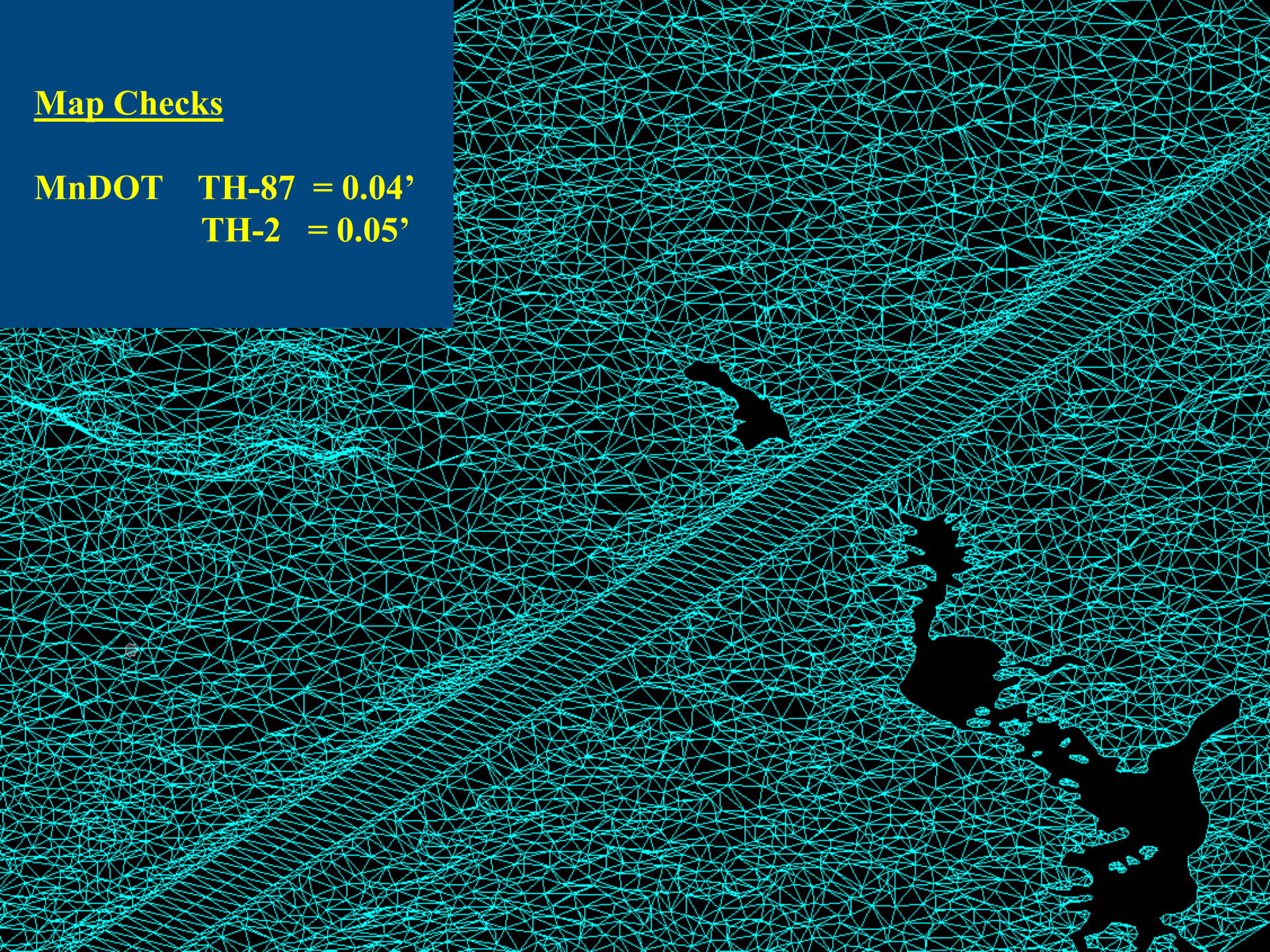
High Density Lidar Approach (>30 ppsm)

The Processes

1) Lidar calibration & imagery AT
2) Edit and classify Lidar point cloud
3) Extract breaklines
4) Extract Model Key Points
5) Planimetric mapping
6) Orthoimagery
7) Surface generation, vertical accuracy assessment and delivery

Map Checks

MnDOT TH-87 = 0.04’
TH-2 = 0.05’



POINT Name/ID	X	Y	FIELD Z	DTM Z	Z Diff	A/B DTM	DIFF SQ	[VALUE]	TOL1	TOL2	TYPE	Raw Description
7	629674.501	327908.838	1199.48	1199.441959	0.038040963	ABOVE	0.001	0.038040963	In	In		CP
15	634070.665	327888.936	1114.925	1114.845183	0.079817127	ABOVE	0.006	0.079817127	In	In		CP
8	642333.244	327608.069	1119.606	1119.569747	0.036252885	ABOVE	0.001	0.036252885	In	In		CP
9	651605.159	327434.002	1222.147	1222.262015	-0.115015258	BELOW	0.013	0.115015258	In	In		CP
12	642624.822	327447.558	1118.897	**1118.933169**	-0.036168941	BELOW	0.001	0.036168941	In	In		CP
13	624517.918	328159.927	1221.736	1221.669389	0.06661124	ABOVE	0.004	0.06661124	In	In		CP
14	624349.851	328300.48	1225.232	1224.988438	0.243562087	ABOVE	0.059	0.243562087	In	In		CP
16	633903.47	327764.082	1114.461	1114.396736	0.064264209	ABOVE	0.004	0.064264209	In	In		CP
17	634827.382	327865.207	1111.94	1111.772246	0.167754029	ABOVE	0.028	0.167754029	In	In		CP
18	635076.77	327758.998	1111.781	1111.811719	-0.030719489	BELOW	0.001	0.030719489	In	In		CP
19	645386.632	327632.51	1154.617	1154.512733	0.10426666	ABOVE	0.011	0.10426666	In	In		CP
20	645612.694	327471.091	1159.325	1159.31227	0.012730365	ABOVE	0	0.012730365	In	In		CP
21	656185.347	327522.031	1255.506	1255.504836	0.001163902	ABOVE	0	0.001163902	In	In		CP
22	656005.281	327412.722	1252.473	1252.499542	-0.026541744	BELOW	0.001	0.026541744	In	In		CP

The Sum of Elev Diff Squared	0.13	
The Average Elev Diff Squared	0.009285714	
The Root Mean Square error	0.096362411	GOAL 0.300'
Vertical 95% Confidence Level (NSSDA)	0.188870326	GOAL +/- 0.588'
% of points w/difference of less then or equal to +/- 0.3'	100	GOAL 90%
% of points w/difference of less then or equal to +/- 0.3'	100	GOAL 95%
The DTM surface is generally DIGGING when compared to the check points (true ground)		
Number of survey points above/below DTM is 10/4	71%/29% split	GOAL 50%/50%
Points Greater than Tolerance of +/- 0.3	0	
Points Greater than Tolerance of +/- 0.3	0	
Maximum difference below	-0.115015258	
Maximum difference above	0.243562087	
Points above surface	10	
Points below surface	4	
Points outside of DTM	2	
Total Points projected onto DTM	14	
Total Points Selected	16	

Map Checks

WISDOT I-94 = 0.09’

AYRES ASSOCIATES

QUESTIONS?

Matt Vinopal, CP, CMS, GISP
vinopalm@ayresassociates.com
608-443-1221

AYRES ASSOCIATES