



2700 61 Avenue SE
Calgary, AB
T2C 4V2

Final Survey Report:

15221 South Central Durham Lidar Survey
For
Central Lake Ontario Conservation Authority

July 17, 2019

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Introduction

In the fall of 2018, Central Lake Ontario Conservation Authority contracted Airborne Imaging to collect LiDAR and Digital Ortho Imagery over South Central Durham. South Central Durham is located in Southern Ontario bordering on Lake Ontario to the south.

In the 2018 acquisition, 385 square kilometers were acquired for Central Lake Ontario Conservation Authority over the South Central Durham area.

This report relates to the Lidar acquisition over the South Central Durham.

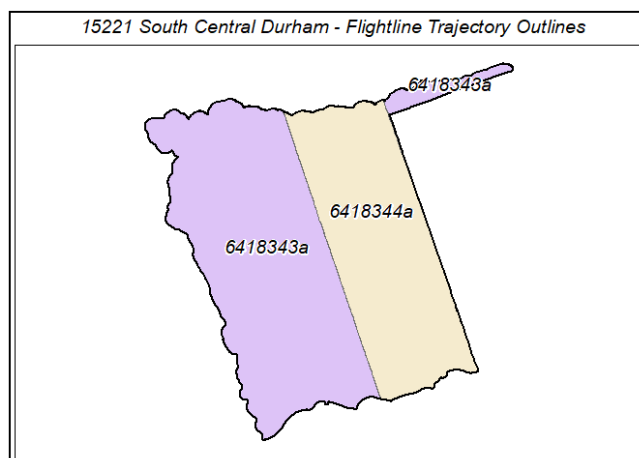
Field Operations

To maximize flight efficiency, two flights were flown in a northwest-southeast azimuth to cover the project area that makes up the South Central Durham AOI. The small northeast portion of the project area was flight planned in an east-west azimuth.

Time line

Two missions were flown on December 9th and 10th, 2018 covering the entire South Central Durham AOI.

See below for a map of the flight trajectory outlines over the AOI of the South Central Durham. The actual flight logs are provided with this report in Appendix B and on the delivery media.



Graphic 1: South Central Durham Flight Trajectories

Personnel

Bruce Whitely, the operations manager was involved in field project management and logistics. Preliminary data processing and system operation was done by Allyson Fox, the field project manager. Ground survey was completed by Allyson Fox.

The data processing was done by half a dozen of geospatial analysts supervised by Kristy O’Grady (Senior Lidar Technical Lead) and David Lavoie (Project Manager / Data Processing Manager).

Equipment

For the 2018 South Central Durham Lidar acquisition, the Lidar system used was a Riegl LMS-VQ1560 (S/N 64) installed aboard a Piper Navajo twin engine aircraft (C-GKSX) from Aries Aviation. More detailed information regarding both the LiDAR system and the aircraft is provided on the delivery media.

Project Parameters

The dual scanner, high pulse rate Riegl LMS-VQ1560 is ideal for large area LiDAR acquisition. The point density resulting from this acquisition meets or exceeds the 11 pts/m² required in the contract prepared by Central Lake Ontario Conservation Authority. Below is a table containing the flight parameters used in the acquisition of this project.

Riegl LMS-VQ1560	
Altitude	1000m AGL
Field of View (FOV)	60°
Air Speed	160 Kts
Pulse Rate	800 kHz (true)
Point Density	~11 pts/m ²

Table 1: Project Parameters for the 2018 South Central Durham LiDAR Collection.

Geodetic Control

See Field Operations section for a more detail of all aspects of the Field Survey and methodologies.

The horizontal datum used is Nad83 CSRS UTM zone 17 (2958) with the CGVD2013 vertical datum (CGG2013 undulation model).

LiDAR Data Processing

Calibration Procedures

The point cloud was initially produced using the latest boresight values for the sensor. Preliminary raster images a produced to ensure data integrity (coverage, intensity values, etc). Once the initial calibrated point cloud and rasters reached the office, an assessment was made by an experienced Lidar Analyst on the calibration and quality of each mission.

BayesMap StripAlign software was used to improve the roll, pitch and DZ values for the missions. Vertical fluctuations can also be solved by this software. LAStools, Global Mapper, Microstation and Terrasolid software applications were also utilized throughout the LiDAR data processing procedures.

Each mission was then compared to each other as well as with the kinematic ground truth to determine if any vertical biases remain (absolute accuracy). Appropriate vertical biases are minimized accordingly by shifting the data vertically.

Below is a table of calibration tracking and any shifting to kinematic ground truthing that was performed.

South Central Durham / Kinematic results					
			Statistics after Bayes Match and after Dz shift (kinematic)		
Mission	Bayes Match	Dz Applied	Dz	Std Dev	RMS
6418343a	Yes	0 cm	-0.008	0.016	0.018
6418344a	Yes	0 cm	0.002	0.014	0.014

Table 2: Calibration Tracking and Statistical Results after Calibration and Shifting

Airborne Imaging has a post-processing methodology designed to use the data from the LiDAR unit and combines the calibration site and overlap analysis to create the most accurate point cloud possible.

Intensity normalization

The native intensity values collected normally fluctuate between approximately 0 and 65535 but differences will be found between missions and flightlines. For this reason, the intensity values are then normalized to 16bit with the Lastools software. The resulting intensities then consistently range between 0 and 65535.

Data Tiling and Classification

The calibrated point cloud is then processed into tiles conforming to the client's requirements. These tiles contain points of all-returns from the LiDAR unit and are stored in individual binary files. In the case of the South Central Durham the tiling was created to match a 1x1km scheme. The tiles were then named according to the UTM coordinate at the lower left of the tile. The naming format used the first 3 digits of the Easting coordinate followed by the first 4 digits of the Northing coordinate. Example: 321_5432.

Point classification was done using the LAStools software, automatically separating points (ground / non ground, low points, high points) by mathematical algorithms. To better understand areas for improvement, the points that are classified as bare earth (ground) are extracted and turned into viewable TIN and grid surfaces. These surfaces are viewed in Microstation/TerraScan in conjunction with

the point cloud for inspection of areas that appear rough, artificially flattened or cut, no data areas, or have other viewable errors. In cleaning up ground points, effort is concentrated in areas where few ground points have been left in the bare earth model and the ground appears rough or lower and flatter than it may be in reality. The scarcity of ground points may be a result of low or no penetration through a dense vegetation layer, or too aggressive values within the classification algorithm. These processes generally involve fixing those areas where the misclassification of features was too aggressive, particularly along mountaintops, ridgelines, shorelines, or other areas of high slope percentage. A manual inspection of these areas plays a major role in resolving any issues or irregularities with the bare earth model.

After the manual inspection of the ground points using the viewable TIN the further classification of bridges and water were to be classified to the appropriate ASPRS classes. Water bodies and water courses meeting specifications of 8000m² (water bodies) and 30m (water courses) nominal width will be delineated and LiDAR points falling within these areas will be classified to the ASPRS water class. Outlier points below ground are classified as class 7 (Low points) and outlier points above ground are classified as class 18 (High points). A manual effort is also made to ensure that bridges have been removed from the bare earth model and are correctly identified and properly classified. Ground above culverts is left in the ground class. This special feature list for this project will include: water and bridge decks. Both Bare Earth and Full Feature grids are created to visually inspect the data. For manual QC purposes Bare Earth grids are produced by using the ground classified points and grids are created from the resulting TINs. Similarly, Full Feature grids are produced by using all non-error points and creating a grid surface of the highest elevations within each cell. Any geographic projections are applied to the final, edited, QC versions of the LAS data.

Once the point cloud has been classified and edited to its final stage the final vertical differences between the ground truth points and the TIN are computed.

Class definitions

As requested in the Central Lake Ontario Conservation Authority contract, the classification followed the ASPRS class codes. The table below shows the classes for the delivered point cloud.

Classification Value	Description
1	Processed but Unclassified
2	Ground
7	Low Points
9	Water
17	Bridge Decks
18	High Points

Table 3: ASPRS Point Classes

Deliverables

Coordinate Transformations

The entire data set was delivered in NAD83 CSRS UTM zone 17, orthometric heights using the Vertical Datum CGG2013.

Deliverables

The deliverables for the South Central Durham project are listed below:

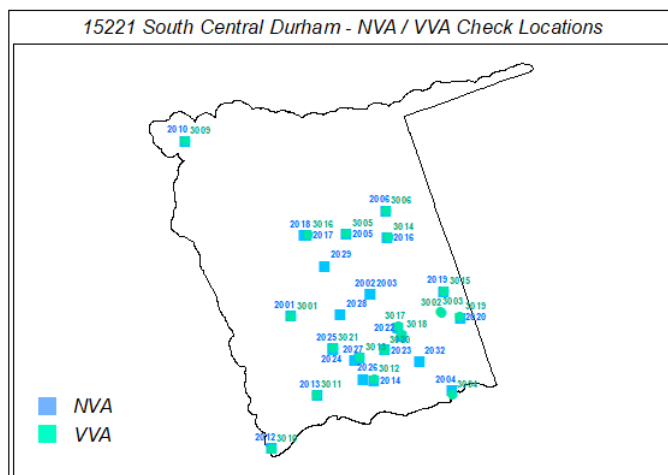
Deliverable	Ext.	Comment
Classified Point Cloud	.las	Tiled in 1x1km scheme / v1.4 georeferencing info embedded in header
Unclassified Point Cloud	.las	Tiled in 1x1km scheme / v1.4 georeferencing info embedded in header
Field Notes / Field Survey	varies	Provided in Appendices as well as on the delivery media
Flightlogs / Flight Information	varies	Provided in Appendices as well as on the delivery media
Data Quality Assurance Report	varies	Documents provided on delivery media and details within the final report
SBETs	.out	SBET provided on delivery media
Metadata	.xml	.xml metadata provided on delivery media
Tile Index / Project Boundary	.shp	Provided on the delivery media
Ground Control Points	.shp .xls	Provided on the delivery media
Lidar Report	.pdf	Provided on the delivery media
50 cm Hydro flattened DEM	.img	Hydro flattened ERDAS Imagine format with no overlap between tiles
50 cm Non hydro flattened DEM and DSM	ESRI Binary	Non hydro flattened DEM and DSM in ESRI binary format with 10m overlap between tiles.
1m Shapefile Contours	.shp	1m shapefile contours created without breakline or hydro enforcement

Table 4: Deliverables

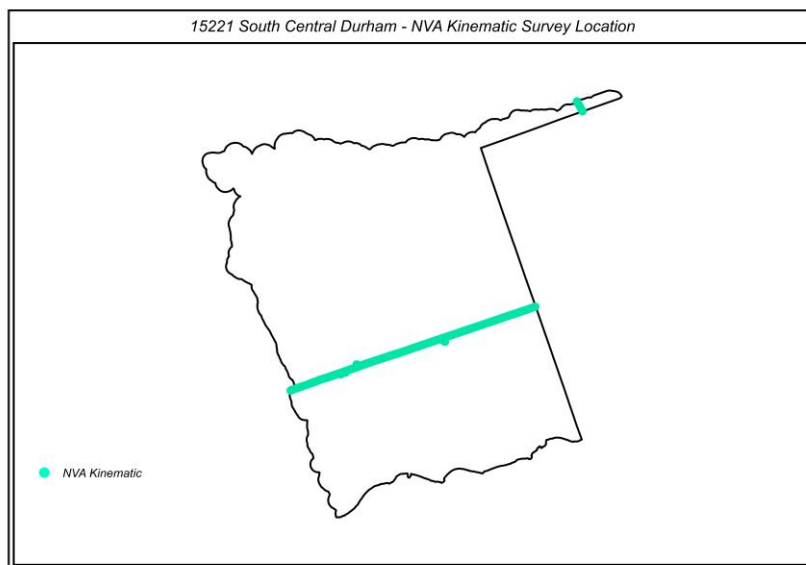
Vertical and Horizontal Accuracy Assessments

During the 2018 field operation, surveying was conducted that produced 26 NVA ground control points and 20 VVA ground control points along with a Kinematic survey of 2502 points along roads in the project area. The kinematic survey was used to shift the data to ground. The RTK NVA and VVA points

were then used as an independent check of accuracy to ground. A listing of all check points is provided on the delivery media along with the graphic of the locations shown below. All check points were collected using RTK surveying methodologies.



Graphic 2: South Central Durham NVA/VVA surveyed check point locations



Graphic 3: South Central Durham Kinematic NVA surveyed point locations

The statistical results for NVA, NVA Kinematic and VVA check points are provided below. The complete listing of sites, dz values between the known z values and statistics are contained on the delivery media.

Kinematic

Below is a summary of the statistics between the point cloud TIN from the ground class and the kinematic points surveyed on the roads within the project area:

NVA Kinematic	
Number of points	2502 pts
Average dz	-0.008 m
Minimum dz	-0.112 m
Maximum dz	0.056 m
Average magnitude	0.016 m
Root mean square	0.02 m
Std deviation	0.018 m
Kinematic Vertical Accuracy (95%)	0.039m

Table 5: NVA Kinematic statistics

This Kinematic vertical accuracy assessment is provided only as a reference. It is biased because during calibration, the point cloud was vertically shifted to these points if it was required. It should not be used as an independent check for accuracy assessments. For a complete listing of the kinematic points and their differences, please refer to the spreadsheet named "SouthCentralDurham_NVA_Kinematic_comparisons_Final.xlsx".

NVA

NVA RTK	
Number of points	26 pts
Average dz	-0.009 m
Minimum dz	-0.042 m
Maximum dz	0.044 m
Average magnitude	0.019 m
Root mean square	0.023 m
Std deviation	0.022 m

Table 6: NVA statistics

The vertical accuracy of this survey expressed in RMS is 2.1 cm or better. The two-sigma accuracy (95%) for a normal distribution is calculated by multiplying the RMSE by 1.96. For this project area, the NVA vertical accuracy results on flat hard surfaces at the 95% confidence level is 4.1 cm or better. See Appendix C for the List of Vertical Differences for the NVA RTK points. The listing was also included as a spreadsheet with the deliverables. Please refer to the spreadsheet named "SouthCentralDurham_NVA_RTK_comparisons_Final.xlsx"

VVA

VVA RTK	
Number of points	19 pts
Average dz	0.078 m
Minimum dz	-0.005 m
Maximum dz	0.158 m
Average magnitude	0.079 m
Root mean square	0.089 m
Std deviation	0.044 m

Table 7: VVA statistics

The vertical accuracy of this survey expressed in RMS is 8.9 cm or better. The 95th percentile of the VVA was determined to be 15.8 cm. See Appendix D for the List of Vertical Differences for the VVA RTK points. The listing was also included as a spreadsheet with the deliverables. Please refer to the spreadsheet named "SouthCentralDurham_VVA_RTK_comparisons_Final.xlsx"

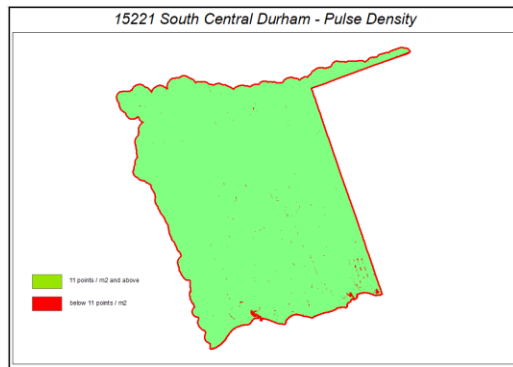
CHA

The calculated horizontal accuracy was determined from the parameters of the LiDAR system used in acquisition and the altitude the project was flown at. The calculated horizontal accuracy at 95% or 2 sigmas was determined to be 29.7 cm or better.

Pulse Density Assessment

A pulse density verification grid is created with 20x20m cells covering the entire project AOI. A visual grid was output that indicated whether each grid cell passed or failed the ANDP requirements for the project. Red indicates cells below ANDP and green indicates those cells meeting or exceeding the requirements. Statistics were examined to quantify pulse density distribution and support the visual graphic output.

A copy of the density raster results of the Pulse Density Check can be found on the delivery media. Below is a graphic of the resulting raster.



Graphic 4: South Central Durham Pulse Density

There are some locations of low pulse density that correspond with acceptable void areas (water courses/water bodies/areas of low reflectivity) throughout the project area.

Conclusion

There were no unforeseen circumstances both at the field and data processing levels and the project went very smoothly.

The vertical and horizontal accuracy results for NVA, VVA and CHA were excellent, being considerably more accurate than the required specifications of 10cm (95% confidence level) NVA, 15.8cm (95th percentile) VVA and 29.7cm (calculated horizontal accuracy).

Appendix A

Daily LiDAR Field Acquisition Report

Daily Lidar Field Acquisition Report

Project: 1730_SouthCentralDurham

Date	Aircraft One Acquisition	C-GKSX Mission 1	System 64 Mission 2	Aircraft Two Acquisition?	Mission 1	Mission 2	Description
November 20, 2018	No						Ground work only - to much snow to fly at this time.
November 21, 2018	No						Ground work only - to much snow to fly at this time.
November 22, 2019	No						Ground work only - to much snow to fly at this time.
November 23, 2019	No						Ground work only - to much snow to fly at this time.
November 24, 2020	No						Ground work only - to much snow to fly at this time.
November 25, 2020	No						Ground work only - to much snow to fly at this time.
November 26, 2021	No						Ground work only - to much snow to fly at this time.
December 9, 2018	Yes	6418343a					Full mission.
December 10, 2018	Yes	6418344a					Completed project.

Appendix B

Mission Flightlogs

Julian Day 343	Flight A	LIDAR Flight Log		
Date December 9 2018 Project 1730_SouthCentral Durham Location Oshawa, Ontario Mission Objective		Aircraft C-GKXSX Pilot Y. Kadota Operator A. Fox		System Riegl Q1560 Unit 2220764 IMU Applanix AP50 GPS Rx Trimble Scanner 1 Drive #3 Scanner 2 Drive #2
		Additional Notes @ 14:00 UTC Temp: -6 Humidity: 73% Pressure: 1028.8 hPa Altimeter: 3035 Terrain Height: 140 m		

Aircraft Block Time			Mission Plan			Static Alignment		GPS Time	
Engine On: 13:57	Ramp Out	Takeoff: 14:20	AGL Height 1000 m	Laser Pulse Rate 800 Hz			Start	End	
Engine Off: 20:28	Ramp In	Landing 20:19	Target Speed 160 kts	Scan Rate 270 Hz			Pre Mission	14:13	
Total 6.5 hrs	Total hrs	Total 6.0 hrs	Laser Current 25 %	FOV 60 Deg's			Post Mission	20:22	
								20:27	

Flight Line	LIDAR File Name	Flight Direction	Flight Altitude	GPS Time		Line Aborted		Comments
				Start	End	Time	nmi to End	
Test strip	----			14:24:41	14:25			
2001	641834301	69	4200/4500	14:29:29	14:31			
2002	641834302	249	42/4500	14:35:54	14:38			
2003	641834303	69	42/4500	14:41:53	14:44			
2004	641834304	249	42/4500	14:48:03	14:51			
X-Tie East	641834305	350	42/4500	14:54:37	14:55			
1048	----	161	34/3600	14:59:17	15:03			ISSUES with Ch1 returns – 0% most of line
1047	641834306	341	34/3600	15:07:54	15:13			
1048	641834307	161	34/3600	15:16:34	15:21			Cloud over water at very end – line ok
1046	----	341		15:24:55		15:26		Very south end clouds over land
1001	641834308	341	38/4000	15:32:20	15:35			
1002	641834309	161	34/3600	15:38:17	15:44			
1003	641834310	341	34/3600	15:47:10	15:53			
1004	641834311	161	34/3600	15:56:43	16:01			
1005	641834312	341	34/3600	16:06:20	16:12			

Julian Day 343	Flight A
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LIDAR Flight Log



Date December 9 2018	Aircraft C-GKSX	System Riegl Q1560	Additional Notes Temp: Humidity: Pressure: Altimeter: Terrain Height:
Project 1730_SouthCentral Durham	Pilot Y. Kadota	Unit 2220764	
Location Oshawa, Ontario	Operator A. Fox	IMU Applanix AP50	
Mission Objective		GPS Rx Trimble	
		Scanner 1 Drive	
		Scanner 2 Drive	

Aircraft Block Time			Mission Plan		Static Alignment	GPS Time	
Engine On. 13:57	Ramp Out	Takeoff. 14:20	AGL Height 1000 m	Laser Pulse Rate 800 Hz	Pre Mission	Start	End
Engine Off. 20:28	Ramp In	Landing 20:19	Target Speed 160 kts	Scan Rate 270 Hz		14:13	14:18
Total 6.5 hrs	Total hrs	Total 6.0 hrs	Laser Current 25 %	FOV 60 Deg's		20:22	20:27

Flight Line	LIDAR File Name	Flight Direction	Flight Altitude	GPS Time		Line Aborted		Comments Time Stamp: 181209_
				Start	End	Time	nmi to End	
1006	641834313	161	34/3600	16:15:45	16:22			
1007	641834314	341	34/3600	16:25:15	16:31			
1008	641834315	161	34/3600	16:34:31	16:40			
1009	641834316	341	34/3600	16:43:30	16:49			
1010	641834317	161	34/3600	16:53:18	16:58			
1011	641834318	341	34/3600	17:02:53	17:09			
1012	641834319	161	34/3600	17:12:04	17:17			
1013	641834320	341	34/3600	17:21:35	17:27			
1014	641834321	161	34/3600	17:30:40	17:36			
1015	641834322	341	34/3600	17:39:35	17:45			Turbulence has picked up
1016	641834323	161	34/3600	17:48:39	17:53			
1017	641834324	341	34/3600	17:57:25	18:03			
1018	641834325	161	34/3600	18:06:21	18:11			
1019	641834326	341	34/3600	18:15:03	18:21			
1020	641834327	161	34/3600	18:24:01	18:29			

Julian Day 343	Flight A
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LIDAR Flight Log



Date December 9 2018	Aircraft C-GKSX
Project 1730_SouthCentral Durham	Pilot Y. Kadota
Location Oshawa, Ontario	Operator A. Fox
Mission Objective	

System Riegl Q1560
Unit 2220764
IMU Applanix AP50
GPS Rx Trimble
Scanner 1 Drive
Scanner 2 Drive

Additional Notes
Temp:
Humidity:
Pressure:
Altimeter:
Terrain Height:

Aircraft Block Time		
Engine On. 13:57	Ramp Out	Takeoff. 14:20
Engine Off. 20:28	Ramp In	Landing 20:19
Total 6.5 hrs	Total hrs	Total 6.0 hrs

Mission Plan		
AGL Height 1000 m	Laser Pulse Rate 800 Hz	
Target Speed 160 kts	Scan Rate 270 Hz	
Laser Current 25 %	FOV 60 Deg's	

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:13	14:18
Post Mission	20:22	20:27

Flight Line	LIDAR File Name	Flight Direction	Flight Altitude	GPS Time		Line Aborted		Comments
				Start	End	Time	nmi to End	
1021	641834328	341	34/3600	18:30:00	18:39			
1022	641834329	161	34/3600	18:42:02	18:47			
1023	641834330	341	34/3600	18:51:21	18:57			
1024	641834331	161	34/3600	19:00:35	19:06			
1025	641834332	341	34/3600	19:09:33	19:15			
1026	641834333	161	34/3600	19:18:51	19:24			
1027	641834334	341	34/3600	19:27:57	19:33			
1028	641834335	161	34/3600	19:37:05	19:42			
1029	641834336	341	34/3600	19:45:50	19:51			
1030	-----	161		19:55:16		19:57		Aborted line due to traffic - re-fly entire line
X-Tie West	641834337	265	34/3600	20:02:52	20:05			Survey ended - time and clouds at north end

Julian Day 344	Flight A
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LIDAR Flight Log



Date December 10 2018	Aircraft C-GKSX
Project 1730_SouthCentral Durham	Pilot Y. Kadota
Location Oshawa, Ontario	Operator A. Fox
Mission Objective	

System Riegl Q1560
Unit 2220764
IMU Applanix AP50
GPS Rx Trimble
Scanner 1 Drive B2
Scanner 2 Drive B1

Additional Notes
Temp: -2
Humidity:
Pressure:
Altimeter: 3019
Terrain Height:

Aircraft Block Time		
Engine On. 14:28	Ramp Out	Takeoff. 14:48
Engine Off. 17:40	Ramp In	Landing 17:27
Total 3.2 hrs	Total hrs	Total 2.7 hrs

Mission Plan		
AGL Height 1000m	Laser Pulse Rate 800 Hz	
Target Speed 160 kts	Scan Rate 270 Hz	
Laser Current 25 %	FOV 60 Deg's	

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:38	14:43
Post Mission	17:33	17:38

Flight Line	LIDAR File Name	Flight Direction	Flight Altitude	GPS Time		Line Aborted		Comments
				Start	End	Time	nmi to End	
Test strip	----			14:52:06	14:52			Time Stamp: 181210_
1030	641834401	341	34/3500	14:55:50	15:01			
1031	641834402	161	34/3500	15:04:27	15:09			
1032	641834403	341	34/3500	15:12:54	15:18			
1033	641834404	161	34/3500	15:21:19	15:26			
1034	641834405	341	34/3500	15:29:29	15:34			
1035	641834406	161	34/3500	15:37:50	15:43			
1036	641834407	341	34/3500	15:46:07	15:51			
1037	641834408	161	34/3500	15:54:19	15:59			
1038	641834409	341	34/3500	16:02:25	16:07			
1039	641834410	161	34/3500	16:10:46	16:15			
1040	641834411	341	34/3500	16:19:13	16:24			
1041	641834412	161	34/3500	16:27:31	16:32			
1042	641834413	341	34/3500	16:35:49	16:41			
1043	641834414	161	34/3500	16:43:53	16:49			

Appendix C

List of Vertical Differences for the NVA RTK Points

Number	Easting	Northing	Known Z	Laser Z	Dz
2001	663248	4864334	126.446	126.42	-0.026
2002	668826.6	4865861	139.523	139.54	0.017
2003	668807.7	4865857	139.788	139.81	0.022
2004	674499.8	4859161	76.739	76.73	-0.009
2005	667131.4	4870096	179.952	179.97	0.018
2006	669881.3	4871688	193.375	193.38	0.005
2010	655863.2	4876548	295.035	295.03	-0.005
2012	661931	4855148	80.758	80.73	-0.028
2013	665065.7	4858801	85.892	85.86	-0.032
2014	669073.5	4859815	88.853	88.82	-0.033
2015	668027.8	4861478	111.508	111.52	0.012
2016	669954.5	4869862	166.092	166.08	-0.012
2017	664353.9	4869992	176.534	176.54	0.006
2018	664210.9	4869969	175.747	175.74	-0.007
2019	673932.6	4866090	144.009	144	-0.009
2020	675048.1	4864238	131.598	131.59	-0.008
2021	670723.9	4863562	113.724	113.73	0.006
2022	670927.7	4862963	103.463	103.43	-0.033
2023	669824.4	4861991	105.322	105.32	-0.002
2024	666230.2	4862072	99.267	99.23	-0.037
2025	666184.2	4862065	97.606	97.65	0.044
2026	668252.7	4859955	91.285	91.27	-0.015
2027	667739.5	4861272	107.132	107.09	-0.042
2028	666680.7	4864420	120.069	120.04	-0.029
2029	665601.8	4867826	152.66	152.66	0
2032	672208.7	4861173	103.142	103.11	-0.032

Average dz	-0.009
Minimum dz	-0.042
Maximum dz	0.044
Average magnitude	0.019
Root mean square	0.023
Std deviation	0.022

Appendix D

List of Vertical Differences for the VVA RTK Points

Number	Easting	Northing	Known Z	Laser Z	Dz
3001	663288.9	4864333	126.776	126.83	0.054
3002	673699.8	4864545	105.097	105.1	0.003
3003	673612.8	4864587	100.091	100.16	0.069
3004	674492.5	4858856	79.115	79.11	-0.005
3005	667150.2	4870079	180.258	180.32	0.062
3006	669892.9	4871655	193.347	193.45	0.103
3009	655834.9	4876554	297.225	297.33	0.105
3010	661930.5	4855067	78.905	79.02	0.115
3011	665056.6	4858819	85.959	86.06	0.101
3012	669049.1	4859910	88.076	88.14	0.064
3013	668060.7	4861481	110.538	110.65	0.112
3014	670040.1	4869816	167.001	167.1	0.099
3015	673937	4866027	142.996	143.04	0.044
3016	664399.9	4869981	176.544	176.64	0.096
3017	670693.1	4863596	113.203	113.36	0.157
3018	670955.6	4863033	100.476	100.54	0.064
3019	675023.5	4864273	131.92	131.95	0.03
3020	669807.8	4861981	104.772	104.93	0.158
3021	666193.6	4862107	102.324	102.38	0.056

Average dz	0.078
Minimum dz	-0.005
Maximum dz	0.158
Average magnitude	0.079
Root mean square	0.089
Std deviation	0.044

Appendix E

Full Control Report

Central Lake Ontario Conservation Authority

South Central Durham LiDAR Acquisition Survey Control Report

Introduction

Airborne Imaging Inc. a Clean Harbors Company, was contracted by Central Lake Ontario Conservation Authority to acquire LiDAR data covering a 395.82 km² area (includes 100m buffer) within the South Central Durham region of Ontario.

Base Stations

In order to acquire the LiDAR data one new control station, A860, was established at the Oshawa Executive Airport, and was observed simultaneously with two NRCAN compliant CAN-Net continuously operating reference stations, CUXB and CBO2 (CAN-Net UXBG and BOV2). Through baseline processing and a rigorous network adjustment, final coordinates were computed for A860. Baseline distances from each CAN-Net station to A860 do not exceed 30 km and during LiDAR acquisition baseline distances from A860 to the aircraft did not exceed 25 km.

Raw GNSS static data for each CAN-Net station and A860 were continuously logged at 1 Hz sample rate and are downloaded in RINEX file format for each hour logged.

NRCAN continuously monitors the CAN-Net stations to ensure coordinate compliance is maintained. Time series monitoring results published weekly and for the period of the ground survey can be found in Appendix B.

Check Point Survey

The CAN-Net stations were also used as base stations for the Real Time Kinematic (RTK) check point survey acquiring a total of 22 vegetated, 32 non-vegetated, and 17 hard surface points with identifiable horizontal features.

During the RTK check point survey one COSINE first order vertical station monument was observed daily as a tie point and to verify each day's survey. A listing comparing the observed coordinate values to the published values can be found in appendix C and final surveyed coordinate values of the check points can be found in Appendix D.

Equipment

Airborne Imaging utilized two Trimble R8 GNSS RTK receivers as RTK rovers, and Can-Net continuously operating reference stations as base stations for the RTK survey and for static observations. The CAN-Net stations are comprised of Trimble NetR9 infrastructure receivers with Zephyr antennas. More information on the CAN-Net network and the NRCAN published coordinates can be viewed at the following links.

<http://gpsweb.can-net.ca/Map/SensorMap.aspx>

<https://webapp.geod.nrcan.gc.ca/geod/data-donnees/rtk.php?locale=en>

- a.) Final Adjusted Coordinates
- b.) Traverse Overview Map
- c.) Traverse Report
- d.) Minimally Constrained Network Adjustment
- e.) Fully Constrained Network Adjustment
- f.) NRCan and COSINE Station Reports
- g.) NRCan CAN-Net Station Monitoring
- h.) Control Station Photos
- i.) Check Point Coordinate Listing

a.) Final Adjusted Coordinates

Project: 1730_SouthCentralDurham_full
 Program: GrafNet Version 8.50.4320
 Profile: Aii Network Summary
 Source: Network

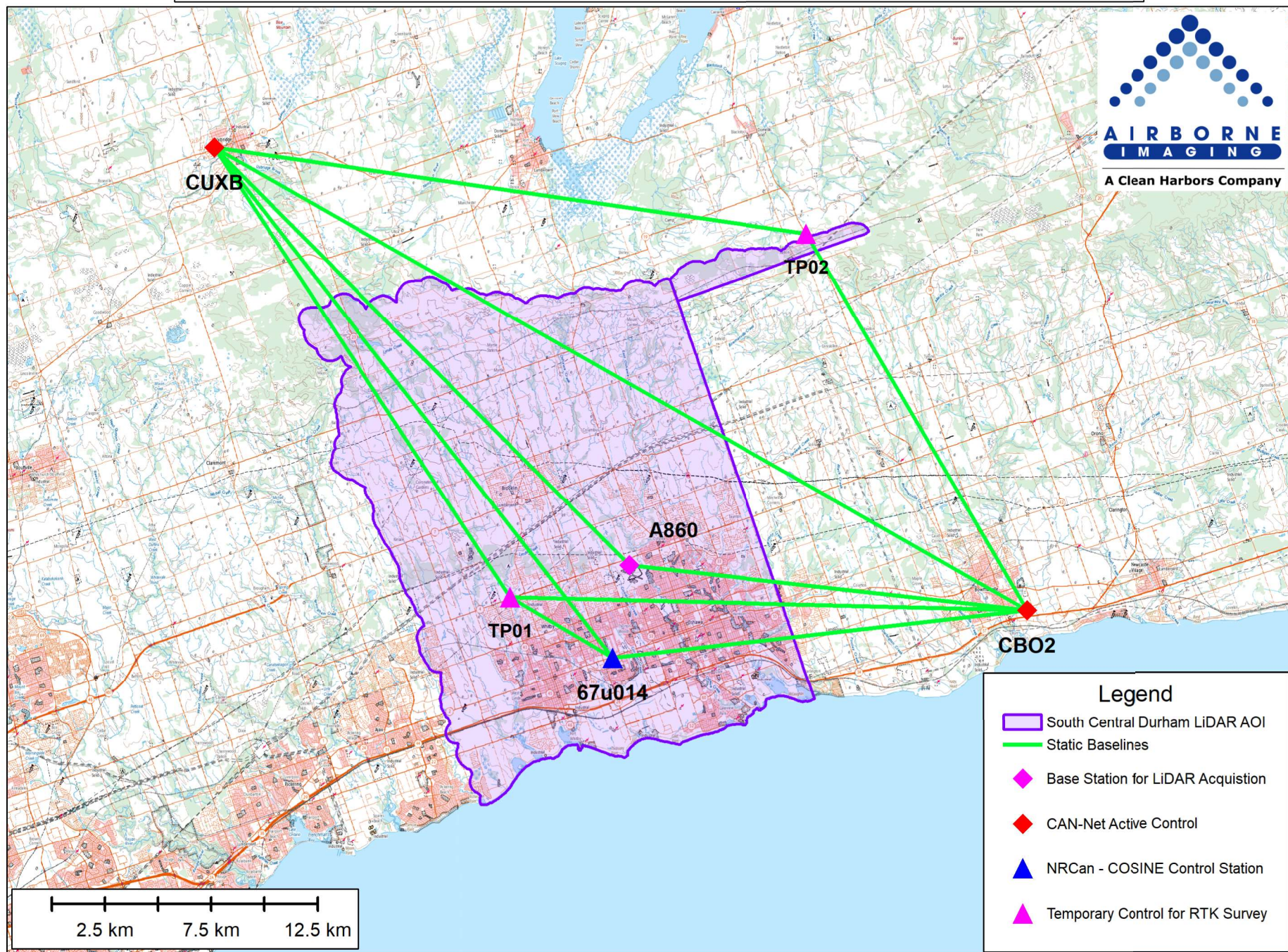
Datum: NAD83, (processing datum)
 Control IDs: UXBG, BOV2, 67u014
 Geoid: CGG2013n83.wpg (Absolute correction)

Map projection Info:
 Defined grid: UTM, Zone 17

Station	Latitude (+/-D M S)	Longitude (+/-D M S)	H-Ell (m)	Undulation (m)	H-MSL (m)	Northing (m)	Easting (m)
67u014	43 53 14.83629	-78 54 27.68462	72.616	-35.927	108.543	4861500.641	668067.361
A860	43 55 34.75065	-78 53 47.66463	103.454	-35.839	139.294	4865840.023	668850.387
BOV2	43 54 10.27549	-78 39 52.52613	59.640	-35.875	95.516	4863734.424	687546.680
TP01	43 54 50.43144	-78 57 59.18562	90.754	-35.874	126.628	4864332.136	663275.475
TP02	44 03 52.90976	-78 47 15.64964	275.998	-35.513	311.512	4881438.216	677179.405
UXBG	44 06 26.55362	-79 08 01.07391	259.719	-35.546	295.265	4885492.470	649365.163

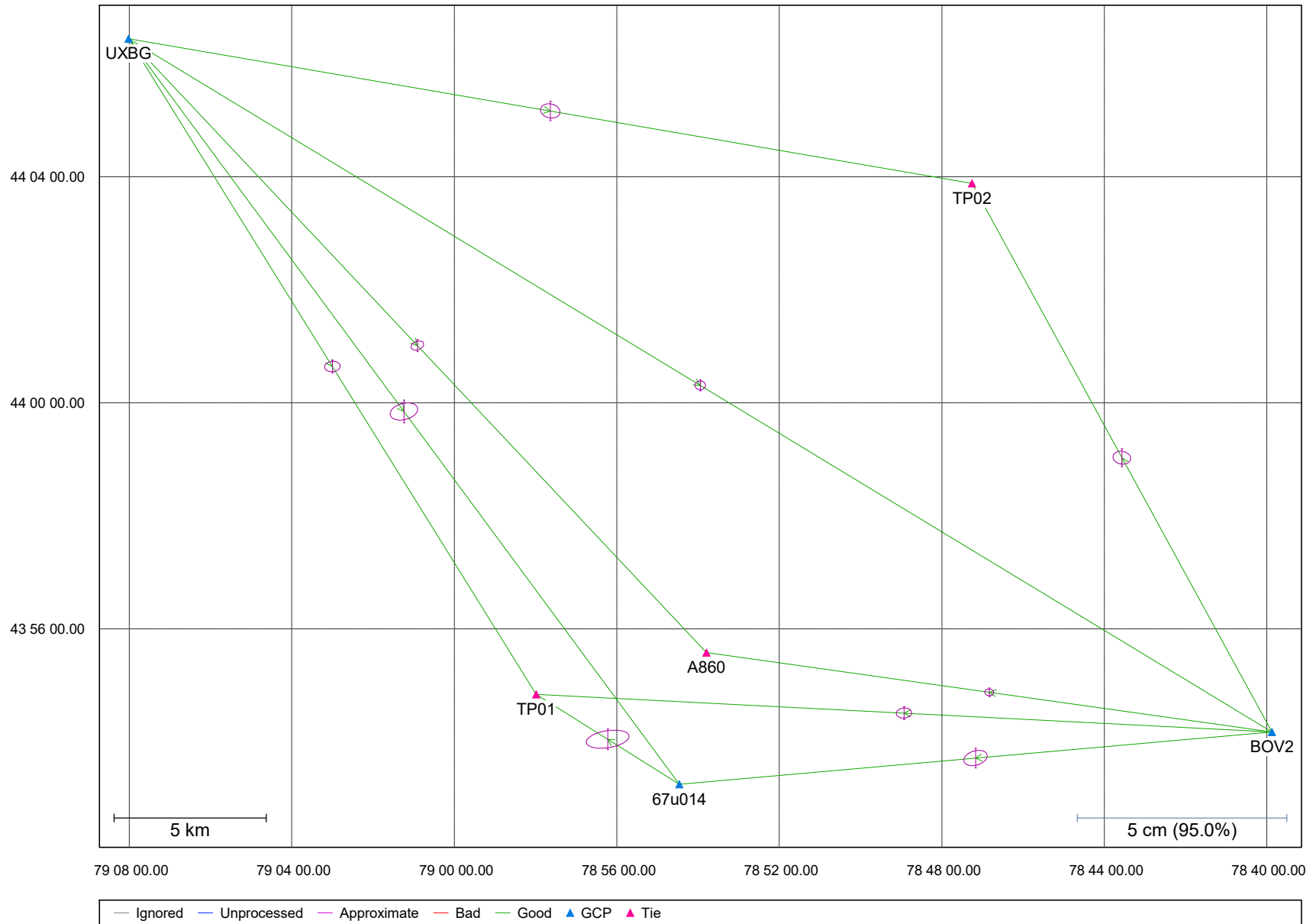
b.) Traverse Overview Map

1730 South Central Durham LiDAR Acquisition Project Control



Traverse - Map

Geographic, DMS



c.) Traverse Report

```

*****
* GrafNet - GRAPHIC GPS NETWORK PROCESSING *
*          SOFTWARE PACKAGE                *
*                                          *
* TRAVERSE SOLUTION:                     *
*                                          *
* Copyright NovAtel Inc. (2014)          *
*                                          *
* Version: 8.50.4320                     *
*                                          *
* PROJECT: 1730_SouthCentralDurham_min   *
*****

```

DATE: 3/11/2019 (m/d/y)
TIME: 11:47:02

DATUM: NAD83
GRID: UTM, Zone 17
UNITS: metres (see Preferences to change)
GEOID: C:\Geoids\Canada\CGG2013n83.wpg

```

*****
STATIONS (STATUS):
*****

```

Station	Type	HgtStatus	Result	Coordinates derived from...
67u014	Check-V	OK	Good	UXBG
A860	Traverse	OK	Good	UXBG
BOV2	Check-3D	OK	Good	UXBG
TP01	Loop Tie	OK	Good	UXBG
TP02	Loop Tie	OK	Good	UXBG
UXBG	Control-3D	OK	Pub (3D)	(-)

```

*****
STATIONS (COORDINATES):
*****

```

Station	Latitude (D M S)	Longitude (D M S)	Grid-E (m)	Grid-N (m)	EllHgt (m)	OrthoHgt (m)
67u014	43 53 14.83617	-78 54 27.68459	668067.361	4861500.637	72.623	108.551
A860	43 55 34.75058	-78 53 47.66458	668850.388	4865840.021	103.457	139.296
BOV2	43 54 10.27541	-78 39 52.52610	687546.681	4863734.422	59.640	95.515
TP01	43 54 50.43146	-78 57 59.18573	663275.473	4864332.136	90.752	126.627
TP02	44 03 52.90978	-78 47 15.64969	677179.404	4881438.217	276.010	311.523
UXBG	44 06 26.55359	-79 08 01.07394	649365.163	4885492.469	259.723	295.269

```

*****
LOOP, CHECK & DUPLICATE TIES:
*****

```

Name/Session	Type	Result	DEast (m)	DNorth (m)	DHeight (m)
POINT 67u014	CheckPnt	Good	(-)	(-)	0.0214
UXBG to A860 (3)	Duplicate	Good	0.0015	-0.0005	0.0014
UXBG to A860 (1)	Duplicate	Good	0.0026	-0.0028	-0.0065
POINT BOV2	CheckPnt	Good	0.0001	-0.0033	-0.0099
UXBG to BOV2 (1)	Duplicate	Good	0.0015	-0.0006	0.0004
UXBG to BOV2 (2)	Duplicate	Good	-0.0005	-0.0000	0.0061
UXBG to BOV2 (3)	Duplicate	Good	0.0020	-0.0020	-0.0150
UXBG to BOV2 (4)	Duplicate	Good	0.0010	-0.0000	-0.0076
UXBG to BOV2 (7)	Duplicate	Good	0.0015	-0.0006	0.0004
67u014 to BOV2	LoopTie	Good	0.0021	-0.0024	-0.0023
A860 to BOV2	LoopTie	Good	0.0002	-0.0008	-0.0027

A860 to BOV2 (3)	Duplicate	Good	0.0002	-0.0003	-0.0010
A860 to BOV2 (4)	Duplicate	Good	-0.0010	0.0015	-0.0115
67u014 to TP01	LoopTie	Good	-0.0068	0.0259	-0.0072
BOV2 to TP01	LoopTie	Good	-0.0046	0.0020	-0.0064
BOV2 to TP02	LoopTie	Good	-0.0023	0.0041	0.0170

RMS (tie points)			0.0026	0.0071	0.0080
RMS (check points)			0.0001	0.0033	0.0167
			=====		

d.) Minimally Constrained Network Adjustment

```

*****
* NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT *
* *
* (c) Copyright NovAtel Inc., (2014) *
* *
* Version: 8.50.4320 *
* *
* FILE: P:\1730_SouthCentralDurham\FieldData\Control Network\Adjustment\17
30_SouthCentralDurham_min.net
*****

```

DATE (m/d/y) : Mon. 3/11/19 TIME: 11:44:14

```

DATUM:          'NAD83'
GRID:           UTM, Zone 17
SCALE_FACTOR:   1.6440
CONFIDENCE LEVEL: 95.00 % (Scale factor is 2.4479)

```

INPUT CONTROL/CHECK POINTS

STA_ID	TYPE	-- LATITUDE --	-- LONGITUDE --	ELLHGT -	HZ-SD	V-SD
67u014	CHK-VT			72.602		
BOV2	CHK-3D	43 54 10.27552	-78 39 52.52610	59.650		
UXBG	GCP-3D	44 06 26.55359	-79 08 01.07394	259.723	0.00500	0.05000

INPUT VECTORS

SESSION NAME	VECTOR(m)	----- Covariance (m) [unscaled] -----
	DX/DY/DZ	standard deviations in brackets
67u014 to BOV2 (1)	18927.1325 4971.4272 1224.0308	3.5144e-006 (0.0019) -2.8185e-006 9.0270e-006 (0.0030) 1.2846e-007 -2.5838e-006 6.1771e-006 (0.0025)
67u014 to TP01 (1)	-5022.4004 1089.3242 2138.5088	6.7469e-006 (0.0026) -6.9980e-006 2.0613e-005 (0.0045) -1.1553e-006 6.0717e-007 2.7365e-005 (0.0052)
A860 to BOV2 (2)	18622.9724 1882.5861 -1908.6055	6.8309e-007 (0.0008) -3.0335e-007 2.5813e-006 (0.0016) 2.3731e-007 -1.3838e-006 2.4191e-006 (0.0016)
A860 to BOV2 (3)	18622.9723 1882.5870 -1908.6070	6.4541e-007 (0.0008) -3.2146e-007 2.3228e-006 (0.0015) 2.4130e-007 -1.4489e-006 2.2012e-006 (0.0015)
A860 to BOV2 (4)	18622.9752 1882.5785 -1908.6011	6.4719e-007 (0.0008) -4.9598e-007 2.4814e-006 (0.0016) 2.9485e-007 -1.2997e-006 2.1659e-006 (0.0015)
BOV2 to TP01 (1)	-23949.5405 -3882.0870 914.4980	1.6540e-006 (0.0013) -1.0133e-006 6.8545e-006 (0.0026) 3.0322e-007 -2.9963e-006 5.6085e-006 (0.0024)

```

BOV2 to TP02 (1)      -12095.9944  2.4689e-006 (0.0016)
                      10164.1692 -1.4467e-006 1.3983e-005 (0.0037)
                      13089.7704  9.6764e-007 -6.4691e-006 8.0102e-006 (0.0028)

UXBG to A860 (3)      21302.7495  2.5816e-006 (0.0016)
                      -9990.9438 -1.4816e-006 5.4101e-006 (0.0023)
                      -14576.3019  9.0664e-007 -3.0267e-006 4.5822e-006 (0.0021)

UXBG to 67u014 (1)    20998.5890  6.3008e-006 (0.0025)
                      -13079.7849 -7.1948e-006 2.3092e-005 (0.0048)
                      -17708.9367  2.5120e-006 -8.8014e-006 1.5018e-005 (0.0039)

UXBG to A860 (1)      21302.7492  8.2087e-007 (0.0009)
                      -9990.9480 -6.2594e-007 3.1513e-006 (0.0018)
                      -14576.2948  3.6879e-007 -1.6507e-006 2.7727e-006 (0.0017)

UXBG to A860 (2)      21302.7513  1.3193e-006 (0.0011)
                      -9990.9448 -6.1026e-007 4.7598e-006 (0.0022)
                      -14576.3013 -2.0566e-007 -3.0362e-006 5.5531e-006 (0.0024)

UXBG to BOV2 (1)      39925.7220  1.3543e-005 (0.0037)
                      -8108.3570  2.6146e-006 9.9553e-005 (0.0100)
                      -16484.9092 -8.8045e-006 -9.9379e-005 1.5271e-004 (0.0124)

UXBG to BOV2 (2)      39925.7232  9.4007e-006 (0.0031)
                      -8108.3529 -4.1103e-006 3.5588e-005 (0.0060)
                      -16484.9135  1.3818e-006 -1.6656e-005 3.5144e-005 (0.0059)

UXBG to BOV2 (3)      39925.7235  5.7009e-006 (0.0024)
                      -8108.3670 -2.1122e-006 1.7451e-005 (0.0042)
                      -16484.8975  1.2815e-006 -9.6437e-006 1.3885e-005 (0.0037)

UXBG to BOV2 (4)      39925.7236  1.1465e-005 (0.0034)
                      -8108.3629 -1.0251e-005 3.3612e-005 (0.0058)
                      -16484.9041  4.9485e-006 -1.6536e-005 2.6283e-005 (0.0051)

UXBG to BOV2 (5)      39925.7236  1.2208e-006 (0.0011)
                      -8108.3573 -6.0351e-007 4.3950e-006 (0.0021)
                      -16484.9093  4.5199e-007 -2.7534e-006 4.1935e-006 (0.0020)

UXBG to BOV2 (7)      39925.7220  1.3543e-005 (0.0037)
                      -8108.3570  2.6146e-006 9.9553e-005 (0.0100)
                      -16484.9092 -8.8045e-006 -9.9379e-005 1.5271e-004 (0.0124)

UXBG to TP01 (2)      15976.1775  1.7164e-006 (0.0013)
                      -11990.4393 -1.0254e-006 7.0903e-006 (0.0027)
                      -15570.4143  3.0024e-007 -3.1660e-006 5.9718e-006 (0.0024)

UXBG to TP02 (1)      27829.7287  2.9284e-006 (0.0017)
                      2055.8022 -1.4936e-006 1.6760e-005 (0.0041)
                      -3395.1241  1.0858e-006 -7.8061e-006 9.8147e-006 (0.0031)

```

```

*****
OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)
*****

```

SESSION NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)	- PPM -	DIST - (km)	STD - (m)
67u014 to BOV2 (1)	0.0013	-0.0036	0.0026	0.235	19.6	0.0055
67u014 to TP01 (1)	-0.0042	0.0217	-0.0008	3.967	5.6	0.0095
A860 to BOV2 (2)	0.0003	-0.0009	0.0012	0.081	18.8	0.0031
A860 to BOV2 (3)	0.0004	-0.0004	0.0029	0.158	18.8	0.0029
A860 to BOV2 (4)	-0.0008	0.0015	-0.0076	0.412	18.8	0.0030
BOV2 to TP01 (1)	-0.0012	-0.0011	-0.0050	0.216	24.3	0.0048

BOV2 to TP02 (1)	-0.0003	0.0012	0.0054	0.270	20.5	0.0063
UXBG to A860 (3)	-0.0002	0.0010	0.0025	0.095	27.7	0.0045
UXBG to 67u014 (1)	-0.0008	0.0025	0.0001	0.086	30.4	0.0085
UXBG to A860 (1)	0.0009	-0.0013	-0.0054	0.203	27.7	0.0033
UXBG to A860 (2)	-0.0017	0.0015	0.0011	0.090	27.7	0.0044
UXBG to BOV2 (1)	-0.0001	0.0008	0.0054	0.124	43.9	0.0209
UXBG to BOV2 (2)	-0.0020	0.0013	0.0111	0.259	43.9	0.0115
UXBG to BOV2 (3)	0.0004	-0.0006	-0.0100	0.227	43.9	0.0078
UXBG to BOV2 (4)	-0.0005	0.0014	-0.0025	0.067	43.9	0.0108
UXBG to BOV2 (5)	-0.0015	0.0014	0.0050	0.124	43.9	0.0040
UXBG to BOV2 (7)	-0.0001	0.0008	0.0054	0.124	43.9	0.0209
UXBG to TP01 (2)	0.0018	-0.0017	0.0065	0.273	25.3	0.0049
UXBG to TP02 (1)	0.0004	-0.0015	-0.0066	0.242	28.1	0.0070

RMS	0.0014	0.0052	0.0054			

\$ - This session is flagged as a 3-sigma outlier

 CHECK POINT RESIDUALS (East, North, Height - Local Level)

STA. NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)
67u014			0.0215
BOV2	-0.0015	-0.0019	-0.0049

RMS	0.0015	0.0019	0.0156

 CONTROL POINT RESIDUALS (ADJUSTMENT MADE)

STA. NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)
UXBG	0.0000	0.0000	-0.0000

RMS	0.0000	0.0000	0.0000

 OUTPUT STATION COORDINATES (LAT/LONG/HT)

STA_ID	-- LATITUDE --	-- LONGITUDE --	ELLHGT -	ORTHOHGT
67u014	43 53 14.83625	-78 54 27.68462	72.6235	108.5509
A860	43 55 34.75062	-78 53 47.66466	103.4578	139.2972
BOV2	43 54 10.27546	-78 39 52.52617	59.6451	95.5205
TP01	43 54 50.43141	-78 57 59.18565	90.7587	126.6330
TP02	44 03 52.90973	-78 47 15.64967	276.0029	311.5163
UXBG	44 06 26.55359	-79 08 01.07394	259.7230	295.2694

 OUTPUT STATION COORDINATES (GRID)

STA_ID	- EASTING - (m)	- NORTHING - (m)	ELLHGT - (m)	ORTHOHGT (m)
67u014	668067.3606	4861500.6398	72.6235	108.5509
A860	668850.3865	4865840.0226	103.4578	139.2972

BOV2	687546.6791	4863734.4230	59.6451	95.5205
TP01	663275.4747	4864332.1348	90.7587	126.6330
TP02	677179.4048	4881438.2154	276.0029	311.5163
UXBG	649365.1627	4885492.4686	259.7230	295.2694

OUTPUT VARIANCE/COVARIANCE

STA_ID	SE/SN/SUP	2 CX matrix (m)----- (95.00 %) (not scaled by confidence level) (m) (ECEF, XYZ cartesian)			
67u014	0.0128	7.3324e-005			
	0.0135	-2.3896e-004	1.2648e-003		
	0.1227	2.3362e-004	-1.2175e-003	1.2307e-003	
A860	0.0123	7.0783e-005			
	0.0124	-2.3651e-004	1.2572e-003		
	0.1224	2.3331e-004	-1.2156e-003	1.2253e-003	
BOV2	0.0124	7.0813e-005			
	0.0124	-2.3652e-004	1.2574e-003		
	0.1225	2.3332e-004	-1.2157e-003	1.2255e-003	
TP01	0.0125	7.1731e-005			
	0.0129	-2.3714e-004	1.2611e-003		
	0.1226	2.3345e-004	-1.2171e-003	1.2286e-003	
TP02	0.0128	7.2688e-005			
	0.0132	-2.3753e-004	1.2687e-003		
	0.1228	2.3406e-004	-1.2208e-003	1.2317e-003	
UXBG	0.0122	7.0350e-005			
	0.0122	-2.3625e-004	1.2557e-003		
	0.1224	2.3318e-004	-1.2147e-003	1.2239e-003	

VARIANCE FACTOR = 1.0000

Note: Values < 1.0 indicate statistics are pessimistic, while
values > 1.0 indicate optimistic statistics. Entering this
value as the network adjustment scale factor will bring
variance factor to one.

e.) Fully Constrained Network Adjustment

```

*****
* NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT *
* *
* (c) Copyright NovAtel Inc., (2014) *
* *
* Version: 8.50.4320 *
* *
* FILE: P:\1730_SouthCentralDurham\FieldData\Control Network\Adjustment\17
30_SouthCentralDurham_full.net
*****

```

DATE(m/d/y): Mon. 3/11/19 TIME: 11:50:46

```

DATUM:          'NAD83'
GRID:           UTM, Zone 17
SCALE_FACTOR:   1.7834
CONFIDENCE LEVEL: 95.00 % (Scale factor is 2.4479)

```

INPUT CONTROL/CHECK POINTS

STA_ID	TYPE	-- LATITUDE --	-- LONGITUDE --	ELLHGT -	HZ-SD	V-SD
67u014	GCP-VT			72.602		0.05000
BOV2	GCP-3D	43 54 10.27552	-78 39 52.52610	59.650	0.00500	0.05000
UXBG	GCP-3D	44 06 26.55359	-79 08 01.07394	259.723	0.00500	0.05000

INPUT VECTORS

SESSION NAME	VECTOR(m)	----- Covariance (m) [unscaled] -----
	DX/DY/DZ	standard deviations in brackets
67u014 to TP01 (1)	-5022.4004 1089.3242 2138.5088	6.7469e-006 (0.0026) -6.9980e-006 2.0613e-005 (0.0045) -1.1553e-006 6.0717e-007 2.7365e-005 (0.0052)
BOV2 to 67u014 (1)	-18927.1345 -4971.4238 -1224.0344	4.8048e-006 (0.0022) -5.2355e-006 1.7900e-005 (0.0042) 1.6580e-006 -7.0730e-006 1.1037e-005 (0.0033)
BOV2 to A860 (2)	-18622.9722 -1882.5870 1908.6064	6.8328e-007 (0.0008) -3.0408e-007 2.5811e-006 (0.0016) 2.3827e-007 -1.3833e-006 2.4188e-006 (0.0016)
BOV2 to A860 (3)	-18622.9721 -1882.5880 1908.6080	6.4563e-007 (0.0008) -3.2228e-007 2.3229e-006 (0.0015) 2.4231e-007 -1.4488e-006 2.2011e-006 (0.0015)
BOV2 to A860 (4)	-18622.9750 -1882.5795 1908.6020	6.4761e-007 (0.0008) -4.9674e-007 2.4811e-006 (0.0016) 2.9568e-007 -1.2994e-006 2.1658e-006 (0.0015)
BOV2 to TP01 (1)	-23949.5405 -3882.0870 914.4980	1.6540e-006 (0.0013) -1.0133e-006 6.8545e-006 (0.0026) 3.0322e-007 -2.9963e-006 5.6085e-006 (0.0024)

```

BOV2 to TP02 (1)      -12095.9944  2.4689e-006 (0.0016)
                      10164.1692 -1.4467e-006 1.3983e-005 (0.0037)
                      13089.7704  9.6764e-007 -6.4691e-006 8.0102e-006 (0.0028)

UXBG to A860 (3)      21302.7495  2.5816e-006 (0.0016)
                      -9990.9438 -1.4816e-006 5.4101e-006 (0.0023)
                      -14576.3019  9.0664e-007 -3.0267e-006 4.5822e-006 (0.0021)

UXBG to 67u014 (1)    20998.5890  6.3008e-006 (0.0025)
                      -13079.7849 -7.1948e-006 2.3092e-005 (0.0048)
                      -17708.9367  2.5120e-006 -8.8014e-006 1.5018e-005 (0.0039)

UXBG to A860 (1)      21302.7492  8.2087e-007 (0.0009)
                      -9990.9480 -6.2594e-007 3.1513e-006 (0.0018)
                      -14576.2948  3.6879e-007 -1.6507e-006 2.7727e-006 (0.0017)

UXBG to A860 (2)      21302.7513  1.3193e-006 (0.0011)
                      -9990.9448 -6.1026e-007 4.7598e-006 (0.0022)
                      -14576.3013 -2.0566e-007 -3.0362e-006 5.5531e-006 (0.0024)

UXBG to BOV2 (1)      39925.7220  1.3543e-005 (0.0037)
                      -8108.3570  2.6146e-006 9.9553e-005 (0.0100)
                      -16484.9092 -8.8045e-006 -9.9379e-005 1.5271e-004 (0.0124)

UXBG to BOV2 (2)      39925.7232  9.4007e-006 (0.0031)
                      -8108.3529 -4.1103e-006 3.5588e-005 (0.0060)
                      -16484.9135  1.3818e-006 -1.6656e-005 3.5144e-005 (0.0059)

UXBG to BOV2 (3)      39925.7235  5.7009e-006 (0.0024)
                      -8108.3670 -2.1122e-006 1.7451e-005 (0.0042)
                      -16484.8975  1.2815e-006 -9.6437e-006 1.3885e-005 (0.0037)

UXBG to BOV2 (4)      39925.7236  1.1465e-005 (0.0034)
                      -8108.3629 -1.0251e-005 3.3612e-005 (0.0058)
                      -16484.9041  4.9485e-006 -1.6536e-005 2.6283e-005 (0.0051)

UXBG to BOV2 (5)      39925.7236  1.2208e-006 (0.0011)
                      -8108.3573 -6.0351e-007 4.3950e-006 (0.0021)
                      -16484.9093  4.5199e-007 -2.7534e-006 4.1935e-006 (0.0020)

UXBG to BOV2 (7)      39925.7220  1.3543e-005 (0.0037)
                      -8108.3570  2.6146e-006 9.9553e-005 (0.0100)
                      -16484.9092 -8.8045e-006 -9.9379e-005 1.5271e-004 (0.0124)

UXBG to TP01 (2)      15976.1775  1.7164e-006 (0.0013)
                      -11990.4393 -1.0254e-006 7.0903e-006 (0.0027)
                      -15570.4143  3.0024e-007 -3.1660e-006 5.9718e-006 (0.0024)

UXBG to TP02 (1)      27829.7287  2.9284e-006 (0.0017)
                      2055.8022 -1.4936e-006 1.6760e-005 (0.0041)
                      -3395.1241  1.0858e-006 -7.8061e-006 9.8147e-006 (0.0031)

```

```

*****
OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)
*****

```

SESSION NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)	- PPM -	DIST - (km)	STD - (m)
67u014 to TP01 (1)	-0.0036	0.0212	0.0019	3.876	5.6	0.0099
BOV2 to 67u014 (1)	-0.0007	0.0041	-0.0006	0.216	19.6	0.0078
BOV2 to A860 (2)	-0.0004	0.0008	-0.0015	0.094	18.8	0.0032
BOV2 to A860 (3)	-0.0004	0.0004	-0.0033	0.178	18.8	0.0030
BOV2 to A860 (4)	0.0008	-0.0014	0.0072	0.392	18.8	0.0031
BOV2 to TP01 (1)	-0.0013	-0.0010	-0.0053	0.230	24.3	0.0050

BOV2 to TP02 (1)	-0.0004	0.0012	0.0056	0.279	20.5	0.0066
UXBG to A860 (3)	-0.0001	0.0010	0.0031	0.116	27.7	0.0047
UXBG to 67u014 (1)	-0.0014	0.0031	-0.0034	0.157	30.4	0.0089
UXBG to A860 (1)	0.0010	-0.0013	-0.0048	0.182	27.7	0.0035
UXBG to A860 (2)	-0.0017	0.0015	0.0017	0.101	27.7	0.0046
UXBG to BOV2 (1)	-0.0000	0.0009	0.0050	0.116	43.9	0.0218
UXBG to BOV2 (2)	-0.0020	0.0014	0.0107	0.250	43.9	0.0120
UXBG to BOV2 (3)	0.0004	-0.0006	-0.0104	0.236	43.9	0.0081
UXBG to BOV2 (4)	-0.0005	0.0014	-0.0029	0.074	43.9	0.0113
UXBG to BOV2 (5)	-0.0015	0.0014	0.0046	0.116	43.9	0.0042
UXBG to BOV2 (7)	-0.0000	0.0009	0.0050	0.116	43.9	0.0218
UXBG to TP01 (2)	0.0018	-0.0016	0.0057	0.246	25.3	0.0051
UXBG to TP02 (1)	0.0004	-0.0015	-0.0068	0.249	28.1	0.0073

RMS	0.0013	0.0051	0.0054			

\$ - This session is flagged as a 3-sigma outlier

 CONTROL POINT RESIDUALS (ADJUSTMENT MADE)

STA. NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)
67u014			0.0137
BOV2	-0.0007	-0.0009	-0.0096
UXBG	0.0007	0.0009	-0.0043

RMS	0.0007	0.0009	0.0100

 OUTPUT STATION COORDINATES (LAT/LONG/HT)

STA_ID	-- LATITUDE --	-- LONGITUDE --	ELLHGT -	ORTHOHGT
67u014	43 53 14.83629	-78 54 27.68462	72.6157	108.5431
A860	43 55 34.75065	-78 53 47.66463	103.4542	139.2936
BOV2	43 54 10.27549	-78 39 52.52613	59.6404	95.5158
TP01	43 54 50.43144	-78 57 59.18562	90.7537	126.6280
TP02	44 03 52.90976	-78 47 15.64964	275.9985	311.5119
UXBG	44 06 26.55362	-79 08 01.07391	259.7187	295.2652

 OUTPUT STATION COORDINATES (GRID)

STA_ID	- EASTING - (m)	- NORTHING - (m)	ELLHGT - (m)	ORTHOHGT (m)
67u014	668067.3606	4861500.6412	72.6157	108.5431
A860	668850.3872	4865840.0235	103.4542	139.2936
BOV2	687546.6798	4863734.4239	59.6404	95.5158
TP01	663275.4753	4864332.1357	90.7537	126.6280
TP02	677179.4055	4881438.2163	275.9985	311.5119
UXBG	649365.1633	4885492.4695	259.7187	295.2652

 OUTPUT VARIANCE/COVARIANCE

```
STA_ID      SE/SN/SUP  ----- CX matrix (m )-----
            (95.00 %) (not scaled by confidence level)
            (m)      (ECEF, XYZ cartesian)
67u014      0.0095    3.1437e-005
            0.0107    -8.2610e-005  4.2857e-004
            0.0709    7.8757e-005  -4.0223e-004  4.1377e-004

A860        0.0087    2.8533e-005
            0.0088    -8.0509e-005  4.2289e-004
            0.0708    7.9175e-005  -4.0355e-004  4.1006e-004

BOV2        0.0087    2.8396e-005
            0.0087    -8.0429e-005  4.2240e-004
            0.0707    7.9131e-005  -4.0326e-004  4.0957e-004

TP01        0.0091    2.9600e-005
            0.0096    -8.1065e-005  4.2641e-004
            0.0710    7.9182e-005  -4.0446e-004  4.1313e-004

TP02        0.0094    3.0654e-005
            0.0100    -8.1659e-005  4.3554e-004
            0.0714    7.9994e-005  -4.0933e-004  4.1706e-004

UXBG        0.0087    2.8383e-005
            0.0087    -8.0397e-005  4.2241e-004
            0.0707    7.9109e-005  -4.0331e-004  4.0966e-004
```

VARIANCE FACTOR = 1.0000

Note: Values < 1.0 indicate statistics are pessimistic, while
values > 1.0 indicate optimistic statistics. Entering this
value as the network adjustment scale factor will bring
variance factor to one.

f.) NRCan and COSINE Station Reports



Station Report - 67U014

Station 1 of 1

Site Identification

Name	Province	NTS map sheet	Unique Number	Provincial Identifier	Network
67U014	Ontario	030M15	67U014		43078

Horizontal Data

Coordinates scaled from map

Geographic

Latitude	Longitude
43° 53' 16.8"	78° 54' 36.0"

UTM

Zone	Easting (metres)	Northing (metres)	Scale
17	667880.285	4861556.529	0.99995

Vertical Data

Vertical Datum	Elevation (m)	Order	Gravity (mGal)	Published	Project ID
CGVD2013 (2010.0)	108.530	1st	980451.02	2013	H13ML1311
CGVD28	108.919	1st	980516.79	1967	VA6
IGLD85	108.986	1st	980619.90	1992	IGLD85AP92



Station Marker

Marker Type	Inspected in	Established by	Status	Comments
Permanent agency marker	1967	Canadian geodetic survey - nrcan	Good	None

Location

Oshawa

Concrete culvert under highway no. 2, 3.9 km west of post office, 1.6 km east of c.p.ry. Bridge, 46 m east of house no. 1115 king street west, tablet in top of culvert, 30 cm from south end, 23 cm from west edge, 2 m below road level.



Station Report - CBO2

Station 1 of 1

Site Identification

Name	Province	NTS map sheet	Unique Number	Provincial Identifier	Network
cannet-BOV2	Ontario	030M15	CBO2		CANNET

Station Coordinates

Coordinates	Geoid	Reference Frame	Epoch
geo	CGG2013a	NAD83(CSRS)	2010

Latitude	Longitude	h (metres)
N43° 54' 10.275517" $\pm$ 0.0021m	W78° 39' 52.526102" $\pm$ 0.0011m	59.650 $\pm$ 0.0033m
$V\phi$ (mm/y)	$V\lambda$ (mm/y)	Vh (mm/y)
-1.43 $\pm$ 0.00	1.61 $\pm$ 0.00	-0.33 $\pm$ 0.00
N (metres)	H (metres)	Published date and project ID
-35.876 $\pm$ 0.009	95.526	2018-04-13 M18-007

Vertical Data

Use the value of H from the coordinates above.

Station Marker

Marker Type	Inspected in	Established by	Status	Comments
Unknown		Cansel (cannet)		None



Station Report - CUXB

Station 1 of 1

Site Identification

Name	Province	NTS map sheet	Unique Number	Provincial Identifier	Network
cannet-UXBG	Ontario	031D03	CUXB		CANNET

Station Coordinates

Coordinates	Geoid	Reference Frame	Epoch
geo	CGG2013a	NAD83(CSRS)	2010

Latitude	Longitude	h (metres)
N44° 06' 26.553595" $\pm$ 0.0007m	W79° 08' 1.073937" $\pm$ 0.0004m	259.723 $\pm$ 0.0011m
$V\phi$ (mm/y)	$V\lambda$ (mm/y)	Vh (mm/y)
-1.61 $\pm$ 0.00	1.64 $\pm$ 0.00	-0.41 $\pm$ 0.00
N (metres)	H (metres)	Published date and project ID
-35.546 $\pm$ 0.010	295.269	2015-09-24 M15-703

Vertical Data

Use the value of H from the coordinates above.

Station Marker

Marker Type	Inspected in	Established by	Status	Comments
Unknown		Cansel (cannet)		None

STATION: 0011967U014

Also known as:	00167U014, 67U014 (stamped on monument)
Monument status:	Existing
Monument type:	BM
Station type:	SPIR
Horizontal datum:	NAD-1983:ORIG
Horizontal accuracy:	UNCLASSIFIED
Latitude:	N43°53'14.8xxxx"
Longitude:	W78°54'27.6xxxx"
Ellipsoidal elevation:	
Ellipsoidal elevation order:	
UTM-17 Easting:	E668067.xxx
UTM-17 Northing:	N4861500.xxx
UTM-17 Cmbd sc-fact:	0.99994742
UTM-17 Mrdnl convg:	1°27'03.0"
MTM-10 Easting:	E352391.xxx
MTM-10 Northing:	N4861001.xxx
MTM-10 Cmbd sc-fact:	0.99992784
MTM-10 Mrdnl convg:	0°24'38.2"
Vertical datum:	CGVD2013
Vertical accuracy:	First order
Orthometric elev:	108.529
Meridional defl:	
Prime vert defl:	
Undulation:	
Location:	WHITBY - CONCRETE CULVERT UNDER Durham Hwy 2 / Dundas Street East, 1.6 KM EAST OF C.PRY. BRIDGE, 46 M EAST OF Springwood St, TABLET IN TOP OF CULVERT, 30 CM FROM SOUTH END, 23 CM FROM WEST EDGE, 2 M BELOW ROAD LEVEL.
Maintenance:	Established by GSC 1967. Inspected by private OLS Mar 2018 - stable.
Other vert data [ord]:	CGVD-1928:1978 [1]
Number of Ref Sketches:	0

g.) NRCan CAN-Net Station Monitoring

Natural Resources Canada CAN-Net Time Series Station Monitoring Results

cannet-BOV2	NRCan	CBO2			
Date(YYYY-MM-DD)	North	East	Vertical	Horizontal	Status
2018-11-21	-0.004	0.004	-0.008	0.006	Station is compliant
2018-11-28	-0.005	0.004	-0.006	0.006	Station is compliant
2018-12-05	-0.004	0.005	-0.008	0.006	Station is compliant

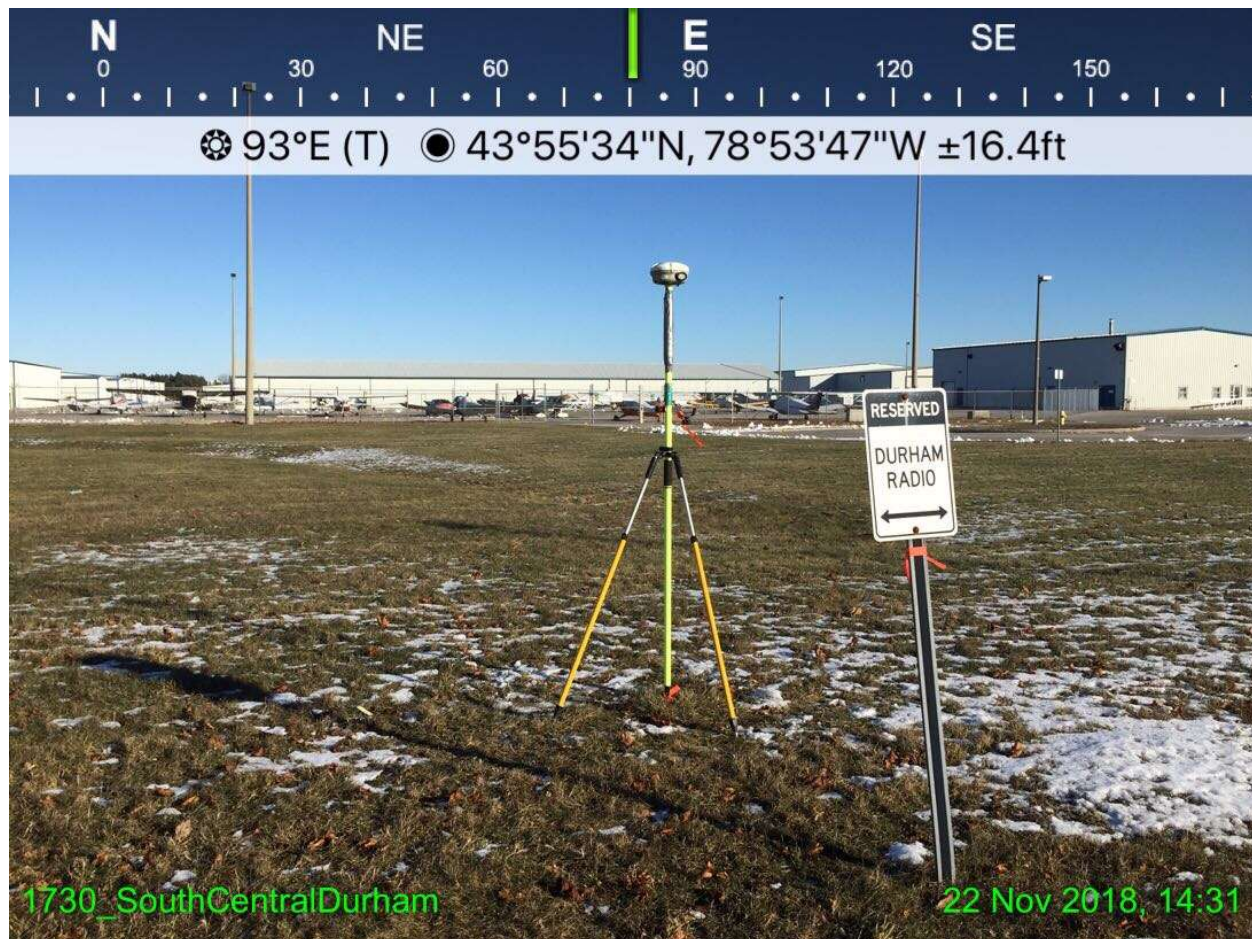
cannet-UXBG	NRCan	CUXB			
Date(YYYY-MM-DD)	North	East	Vertical	Horizontal	Status
2018-11-21	0.000	0.003	-0.012	0.003	Station is compliant
2018-11-28	-0.003	0.004	-0.009	0.005	Station is compliant
2018-12-05	-0.001	0.005	-0.011	0.005	Station is compliant

h.) Control Station Photos

COSINE 0011967U014
NRCan 67U014



A860



i.) Check Point Coordinate Listing

Horizontal Check Points

**NAD83 CSRS (2010), UTM Zone 17
CGVD2013**

PointID	Easting	Northing	Elevation		Comment
4001	663237.654	4864328.446	126.943	horizontal	
4002	668826.622	4865860.581	139.525	horizontal	paint line
4003	674615.026	4858958.686	79.182	horizontal	corner in walkway
4004	655833.302	4876531.425	295.655	horizontal	paint line
4005	664383.384	4870005.250	176.142	horizontal	paint line
4006	658494.550	4863818.711	120.673	horizontal	paint line
4007	661921.944	4855101.632	79.834	horizontal	corner of concrete
4008	661937.390	4855072.324	79.459	horizontal	corner of concrete
4009	665057.800	4858827.204	86.695	horizontal	electrical box corner
4010	669051.751	4859882.024	89.175	horizontal	corner of concrete
4011	668040.044	4861495.291	111.546	horizontal	paint line
4012	669940.718	4869854.665	165.830	horizontal	paint line
4013	673939.681	4866064.777	143.792	horizontal	corner of concrete
4014	675045.033	4864248.861	131.637	horizontal	corner of concrete
4015	670758.875	4863577.979	114.175	horizontal	paint line
4016	669827.130	4861980.078	105.295	horizontal	paint line
4017	666225.762	4862060.610	99.460	horizontal	corner of concrete

Non Vegetated Check Points

**NAD83 CSRS (2010), UTM Zone 17
CGVD2013**

PointID	Easting	Northing	Elevation	Comment	
2001	663247.957	4864333.889	126.446	hard surface	
2002	668826.620	4865860.585	139.523	horizontal	paint line
2003	668807.728	4865857.148	139.788	hard surface	
2004	674499.797	4859161.007	76.739	hard surface	
2005	667131.371	4870095.707	179.952	hard surface	highway
2006	669881.338	4871687.818	193.375	hard surface	highway
2007	679560.414	4876324.364	251.257	hard surface	paved area
2008	676704.008	4882170.792	304.434	hard surface	paved area
2009	666330.206	4879523.478	273.152	hard surface	paved area
2010	655863.188	4876548.479	295.035	hard surface	paved area
2011	658500.435	4863832.417	120.952	hard surface	paved area
2012	661930.950	4855147.890	80.758	hard surface	paved area
2013	665065.710	4858800.813	85.892	hard surface	paved area
2014	669073.513	4859814.751	88.853	hard surface	paved area
2015	668027.793	4861477.551	111.508	hard surface	paved area
2016	669954.524	4869861.989	166.092	horizontal	paint line
2017	664353.872	4869991.921	176.534	hard surface	paved area
2018	664210.865	4869969.478	175.747	hard surface	paved area
2019	673932.616	4866089.540	144.009	hard surface	paved area
2020	675048.098	4864238.389	131.598	hard surface	paved area
2021	670723.927	4863562.293	113.724	hard surface	paved area
2022	670927.650	4862963.122	103.463	hard surface	paved area
2023	669824.407	4861990.990	105.322	hard surface	paved area
2024	666230.234	4862072.441	99.267	hard surface	paved area
2025	666184.211	4862064.947	97.606	hard surface	baseball diamond
2026	668252.727	4859954.846	91.285	hard surface	paved area
2027	667739.547	4861271.535	107.132	hard surface	paved area
2028	666680.658	4864420.257	120.069	hard surface	paved area
2029	665601.769	4867825.640	152.660	hard surface	paved area
2030	662633.930	4879312.391	302.102	hard surface	paved area
2031	666232.673	4878801.544	299.761	hard surface	paved area
2032	672208.696	4861172.848	103.142	hard surface	paved area

Vegetated Check Points

**NAD83 CSRS (2010), UTM Zone 17
CGVD2013**

PointID	Easting	Northing	Elevation	Comment	
3001	663288.926	4864332.943	126.776	vegetation	
3002	673699.779	4864545.096	105.097	hard surface	
3003	673612.830	4864586.943	100.091	vegetation	
3004	674492.498	4858856.252	79.115	vegetation	bushes
3005	667150.246	4870078.509	180.258	vegetation	tall grass
3006	669892.949	4871655.252	193.347	vegetation	tall grass
3007	677151.603	4881484.577	311.302	hard surface	paved area
3008	666358.549	4879530.279	272.652	vegetation	tall grass
3009	655834.939	4876553.996	297.225	vegetation	tall grass
3010	661930.520	4855067.257	78.905	vegetation	tall grass
3011	665056.627	4858819.458	85.959	vegetation	tall grass
3012	669049.108	4859910.211	88.076	vegetation	tall grass
3013	668060.688	4861481.321	110.538	vegetation	tall grass
3014	670040.107	4869816.182	167.001	vegetation	tall grass
3015	673937.023	4866027.459	142.996	vegetation	tall grass
3016	664399.895	4869981.201	176.544	low brush	
3017	670693.147	4863595.886	113.203	vegetation	
3018	670955.567	4863033.482	100.476	vegetation	bushes
3019	675023.530	4864272.510	131.920	vegetation	tall grass
3020	669807.779	4861980.549	104.772	vegetation	
3021	666193.602	4862106.600	102.324	vegetation	grass
3022	662639.719	4879320.199	301.000	vegetation	tall grass