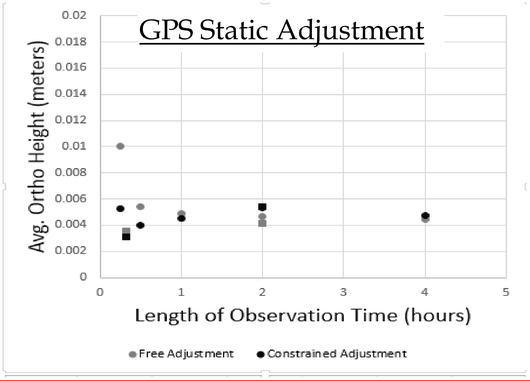
SURVEYING ENGINEERING: ELEVATION DATA COMPARISON



The above graph represents a static GPS adjustment that utilizes the maximum number of available Continuously Operating Reference Stations (CORS) as control points in order to solve for the heights of the unknown stations. The zero value on the Y axis represents 2nd Order Class I Level heights. The dots on the graph represent the Root Mean Square Error of individual static solutions as they varied from the control height. A free adjustment does not hold any value as a true value, but a constrained adjustment held the elevation at MDOT vertical control monument at 54603 as true.

Estimated Cost of Project

Monument Reconnaissance : 17 HRS @ $40.00=	$680.00
Training: 18 HRS @ $40.00=	$720.00
2nd Order Vertical Control: 91 HRS @ $40.00=	$3640.00
Static GPS: 24 HRS @ $40.00=	$960.00
Laser Scanning, 3– Wire, and Traverse: 31 HRS @ $40.00=	$1240.00
RTK GPS: 3 HRS @ $40.00=	$120.00
Data Processing: 6 HRS @ 40.00=	$240.00
Survey and Design Total= $7,600 X 3 (Profit Factor)	$22,800.00
Office Administrative, Safety, and Licensing=	$5000.00
Equipment Usage=	$5000.00
Liability and Subrogation=	$5000.00

Total = $37,800

Team Members:

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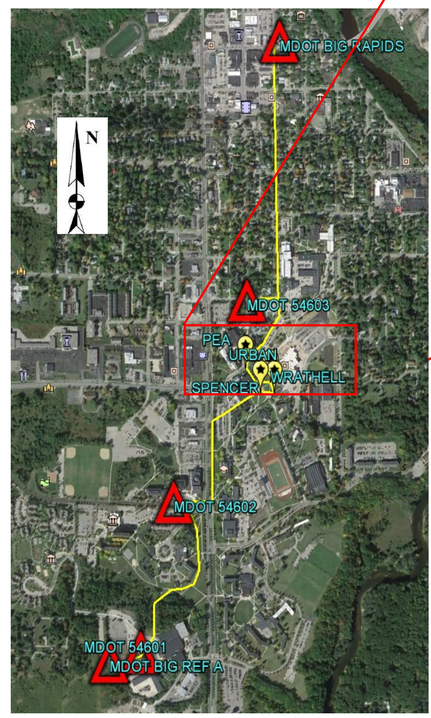
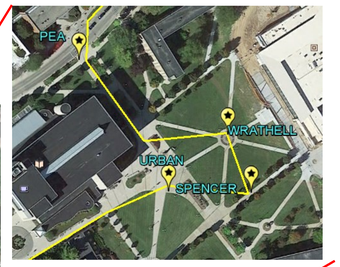
Scope of Work: The primary goal of this project was to establish a 2nd Order Vertical Control Network consisting of four points on Ferris State University campus. This network can be used by future students for class projects and research. The second goal of this project was to perform a quality assessment achieved by various other measurement techniques such as: traversing, 3-wire leveling, laser scanning, and GPS. These were compared to the established vertical control network points, which were assumed to be the true height values. The results of the comparative study will be used to determine the suitability of alternate height measurement techniques, in addition to preparing the group for future project planning and to understand which instruments to use for various projects. While traversing and 3-wire leveling have been used by surveyors to determine vertical height in the past, a portion of this study was to determine how accurate laser scanning and GPS (static and RTK) are in regards to the height measurements. The group was able to combine and expand the information learned throughout their education and experience at Ferris State University.

Measurement Technique	PEA	WRATHELL	SPENCER	URBAN	MDOT 54603
2nd Order Class I Leveling	290.70771	289.94243	289.34393	290.55665	298.66891
Three Wire Leveling	290.70445 (0.00326)	289.93893 (0.0035)	289.34051 (0.00342)	290.55310 (0.00355)	298.69891 (0.00)
Traverse	290.7134 (-0.00569)	289.9463 (-0.00387)	289.3488 (-0.00487)	290.5644 (-0.00775)	298.66891 (0.00)
RTK GPS (AM SESSION) 9:15-10:15	290.7058 (0.00191)	289.9394 (0.00303)	289.3497 (-0.00577)	290.555 (0.00165)	298.670 (-0.00109)
RTK GPS (PM SESSION) 1:30-2:15	290.7134 (-0.00569)	289.9432 (-0.00077)	289.3432 (0.00073)	290.5569 (-0.00025)	298.663 (0.00591)
Static GPS	290.7074 (0.00031)	289.9459 (-0.00347)	289.3388 (0.00513)	290.5575 (-0.00085)	298.66891 (0.00)
LiDAR	290.59084 (0.11687)	289.85077 (0.09166)	289.28384 (0.06009)	290.56158 (-0.00493)	298.63267 (0.03624)

(All measurements in METERS)

In the chart to the left is a comparison between each elevation data collection technique. The 2nd Order Class I Leveling was held as the true height and the differences between each technique was calculated. Below that chart are the 2nd Order Class One leveled heights for each MDOT vertical control monument.

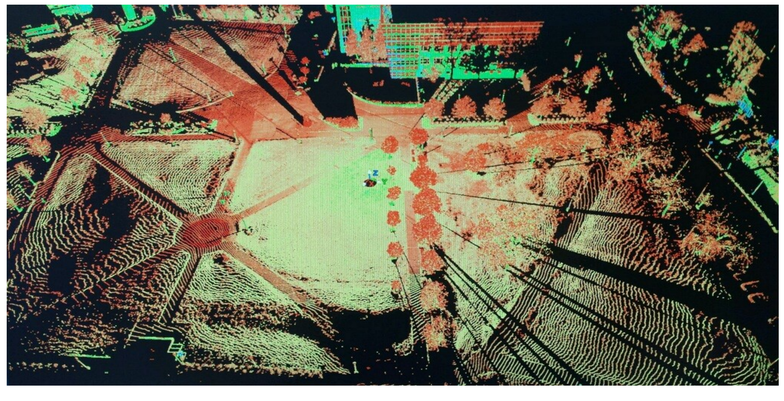




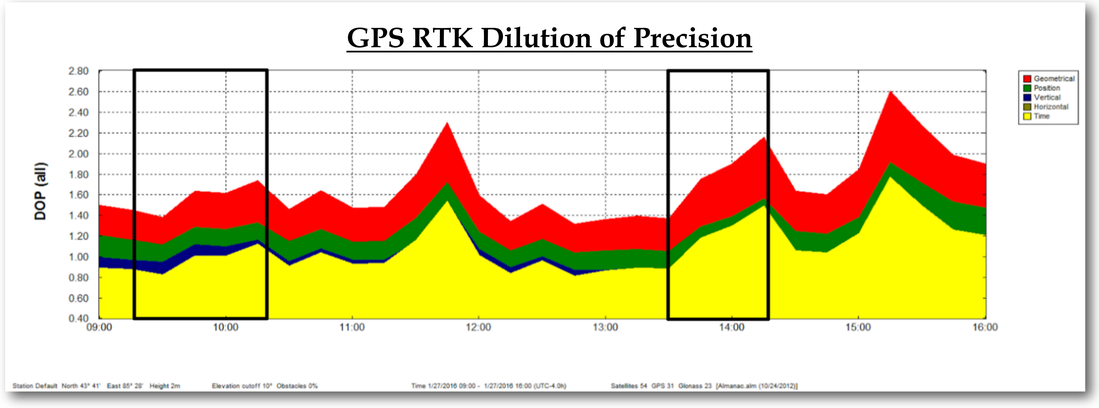
In the image to the left is the route to establish the 2nd Order Class I vertical control on the four Ferris campus monuments. The route consisted of two MDOT vertical control monuments to the north and three MDOT vertical control monuments to the south of the Ferris campus monuments. To meet National Geodetic Survey standards, these MDOT monuments were required to establish the orthometric heights on the Ferris monuments. The loop was approximately 3.7 kilometers (2.3 miles) and took about 26 hours to complete.

Measurement Technique	MDOT BIG RAPIDS	MDOT 54603	MDOT 54602	MDOT 54601	MDOT BIG REF A
2nd Order Class I Leveling	285.58160	298.66891	298.90562	316.67851	313.01412

(All measurements in METERS)



In the above picture is a point cloud of laser data of the Ferris State campus quad. The points were collected with a Leica P40 ScanStation. The point cloud is a representation of multiple scan set-ups that were registered together in Cyclone, a Leica data processing software. The point cloud data was not very dense because the scanning targets were set-up too far apart during the field work and the targets were not registered in the field. If the traverse of the laser scan had more set ups with closer targets, the deliverable of the above scan would be more dense and the elevations on the four campus control points would be more easily determined.



The above graph is a representation of the Real Time Kinetic GPS dilution of precision (DOP) for January 27, 2016. DOP is mathematical algorithm that models the effects of satellite positions. For optimum results, it is best to have a low DOP when taking GPS measurements. The boxed areas represent the time at which we gathered our observations: 9:15 am - 10:15 am and 1:30 pm—2:15 pm. We chose to do our observations in the morning and afternoon because of atmospheric conditions and satellite positions change throughout the day. These two conditions are likely to effect our results. Both the am and pm observation results are shown in the data comparison table.

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