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I. Introduction

Surveying is a necessary activity to determine the elevations, distances, and angles for a specific plot of land. This information can be obtained to varying degrees of accuracy through different surveying methods. To obtain an accurate description of the land are outside of Old Main Building on the campus of The Pennsylvania State University in University Park, Pennsylvania, six laboratories were conducted. Included in this report is a complete analysis of four of these labs that are required to produce a contour map of the area that is defined by University markers 33, 73, and 53.

The four labs covered in this report are "Pace Calibration and Traverse Pacing", "Differential Leveling and Circuit Adjustment", "Horizontal Distance and Angle Measurement Using the Total Station", and Topographic Map Details Obtained with Total Station." Each of these surveys was performed separately with different methods. However, each laboratory exercise builds on the previous data collected by providing additional and more accurate information related to the position of each traverse point.

The first surveying exercise included is a traverse pacing exercise. In this laboratory, individual group member's paces and a compass were used to determine rough values for the lengths and relative angles of the traverse legs. Next, a level circuit around Old Main Lawn was completed. The circuit began and ended at benchmarks, which are permanent objects with a marked point whose elevation above a datum is known. These can be located by contacting the local code authority, Center Region Code Administration in this region. Since these elevations are known, the elevations of other points in the survey can be determined by comparison to these points. The third lab of relevance to this report measures horizontal distances and angles between points. This can be used in combination with the information from previous labs to find northing and easting coordinates of each point. The final step in creating a complete survey is to develop a topographic map based on the boundaries created by the traverse. This map shows relationships between all features within the traverse.

The accuracy of a topographic map is of critical importance. If the map created is not accurate it could cause conflicts in zoning and construction projects. Therefore, each survey is held to a certain degree of accuracy. Measures are taken to ensure that the error does not exceed a certain level, and corrections are made for random errors. Each survey exercise covered in this report is held to an increasingly high degree of accuracy. Error calculations are shown and the adjustments are shown in appendix A.

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II. Explanation of Labs

Field Lab 2: Pace Calibration and Traverse Pacing

Purpose: The purpose of this procedure was to determine the length of each crew member's pace in order to obtain a rough measurement of the traverse length. It also familiarized the survey team with the traverse points which would later be further investigated.

Date: 10 September 2002

Equipment: 30m open reel fiberglass tape
Site poles
Compass

Method: The first step of this lab was to calibrate each person's pace. It is difficult to maintain a completely uniform pace size. Therefore, it is important to take an average of several separate trials for pacing a single given distance. Two range poles were set at a distance of thirty meters as measured by the thirty meter fiberglass tape. Each crew member paced the distance between these poles ten times, five times in each direction. The number of paces per thirty meters was averaged for each group member and divided by thirty to calibrate each person's pace size.

The next step was to determine the distance between the points in the traverse by having someone in the group pace each leg. Each leg was paced twice, once in each direction by a different group member. The average number of paces was multiplied by the pacer's average length of pace to find an approximate distance between the two traverse points.

While the pacer was at each point, she used a compass to determine the azimuth of the leg she was measuring. Both the azimuth and back azimuth were measured and then corrected for an eleven degree west declination and averaged.

Error Statement: Error calculation and correction were not computed for this lab. However, the azimuths were adjusted for the eleven degree west declination for State College in 2002.

Field Lab 3: Differential Leveling and Circuit Adjustment

Purpose: The purpose of this surveying session was to determine the adjusted elevations of each point in the traverse and to gain familiarity with the procedure for doing this.

Date: 17 September 2002

Equipment: Automatic Level
Fiberglass Level Rod
Rod Level
Turning Point
Tripod

Method: Beginning at the benchmark location outside of Sackett, the survey team completed a level circuit around Old Main Lawn including each traverse station (33, 73, and 53) as well as two turning points ending at the Old Main benchmark. Through this level circuit, the team determined the elevations of each point in the circuit. By beginning and closing the circuit on benchmarks, the known elevations could be used to determine the error of the survey and correct the elevations. To begin the survey, the automatic level was set up midway between the Sackett benchmark and the traverse point 73. The benchmark was used as the backsight and the traverse point was used as the foresight. This process was repeated as the group moved from traverse point 73 to 53 to 33. Two turning points were then used before the traverse was closed at the benchmark on the steps of Old Main.

Error Statement: Once the traverse was closed, the actual closure was calculate and compared to the allowable closure. The actual closure of +0.013 m was less than the allowable closure of 0.01415 m. Therefore, the survey was determined to be acceptable and elevation adjustments were calculated. Adjustments were rounded to the nearest 0.005 m and added to the measured elevations. A table of these adjustments and the adjusted elevations can be found in the appendix.

Field Lab 5: Horizontal Distance and Angle Measurement Using the Total Station

Purpose: The purpose of this field lab is to determine the length of the sides of the traverse and to become familiar with the procedure for horizontal distance measurement by EDM (total station) using a prism pole and reflector. We determined the adjusted interior horizontal angles of a geometrically closed traverse and became familiar with the 1DR method for horizontal angle measurement using the total station and plumb bobs.

Date: October 1, 2002

Equipment: Sokkia SET5A Total Station
Prism Pole with reflector
Two (2) Plumb Bobs

Method: The first step in the performance of this field laboratory was to note the field temperature and atmospheric pressure. This was done in order to set the atmospheric correction for the SET5A Total Station.

To begin the traverse measurements, our group first set the total station up at station 33. We indexed the H and V circles and set the atmospheric correction in the instrument. The prism constant was then checked for correctness and set to -30mm. Lastly, the eyepiece was adjusted to remove parallax. The rod person stood at station 53 and we zeroed the instrument. Now the rod person moved to station 73, and the other group members measured the angle between them. We now set up the total station at station 73, and repeated the procedure for stations 33 and 53.

Moving in a counter-clockwise direction, our group measured the length of the sides of the traverse two times each, once forward and once reverse. We also measured the interior angles of the traverse using the 1DR method.

Error Statement: The allowable closure was 00°00’13”. The actual closure that was obtained by our group was 00°00’10”. Since $|C_{ACT}| < C_{ALLOW}$, the survey is acceptable.

Field Lab 6: Topographic Map Details Obtained with Total Station

Purpose: The purpose of this lab is to perform a radial survey from a known baseline to determine horizontal and vertical locations (x,y,z) of various points and collect topographic map information within a defined area.

Date: October 22, 2002

Equipment: Sokkia SET5A Total Station
Prism Pole with Reflector
Fiberglass Tape

Method: Our group began this field lab by setting up the total station at traverse point 33. This point and the triangular area for the survey were defined by our lab teaching assistant, Dan Luther. We then proceeded to take twenty (20) shots, based on two crew members at ten (10) shots each, to define the traverse area.

The process to take these shots was to use the prism pole in order to shoot distances and elevations of various points along the triangle and in the surrounding area. We shot distances and elevations of points and natural objects such as stations 53 and 73, sidewalks, and random points of swells and depressions within the traverse area.

The height of the prism pole was measured to the nearest centimeter. During the shots, group members used the THEOdolite mode on the total station to find angles. The EDM mode and *Sdist* were used to measure the slope distance, horizontal and vertical angles. This was done for each of the twenty (20) shots recorded in the field book.

Error Statement: The use of the total station minimized error in measurement. The main source of error in this field lab comes from reducing all field notes with horizontal distances and elevations to the nearest 1cm.

III. Office Computations Methods

Pace Calibration and Traverse Pacing

Given: West Declination = 10°36' (rounded to 11° for the purpose of these calculations)

Azimuth Angle = Measured Angle - 11°
Back Azimuth = Azimuth + 180°

Table A - Pace Calibration Data

Trial	Field Data for Michelle Mentzer		Field Data for Erin Hess		Filed Data for Kelly Hellyer*	
	# of paces	distance paced (m)	# of paces	distance paced (m)	# of paces	distance paced (m)
1	42.0	30		30		30
2	40.9	30		30		30
3	42.5	30		30		30
4	42.1	30		30		30
5	43.0	30		30		30
6	42.0	30		30		30
7	43.1	30		30		30
8	41.9	30		30		30
9	42.6	30		30		30
10	41.2	30		30		30
Sum	421.3	30		30		30
Average	42.13	30		30		30
Length of Pace	0.712	30		30	0.693	30

*Since Kelly dropped the class after the first few labs, her pacing information is not available.

The computations for this lab include averaging of paces over a given distance and dividing the controlled distance by this value to give a pace length for each crew member. The number of paces in each leg of the traverse was then multiplied by the pacing crew member's pace size to determine the length of that leg. The angles between points were measured with a compass, adjusted by 11° and averaged by subtracting 180° from the back azimuth, adding it to the azimuth and dividing by two.

Table B - Traverse Pacing Summary of Field Data & Results

Individual Pacing	Station From	Station To	# of Paces	Distance Paced	Azimuth Angle*
Michelle	73	33	154	109.6	39°
	33	73	155	110.4	40°
			Sum:	220.0	79°
			Average:	110.0	40°
Kelly	53	33	110.1	76.3	191°
	33	53	112.5	78	8°
			Sum:	154.3	379°
			Average:	77.2	190°
Erin	53	73	90.0	67.5	274°
	73	53	85.0	63.8	85°
			Sum:	131.3	539°
			Average:	65.7	270°

*Azimuth Angles shown have been adjusted for the 11° West Declination

Differential Leveling and Circuit Adjustment

Given: 1. Sackett Benchmark Elevation = 353.549 m
2. Old Main Benchmark Elevation = 356.134 m

Allowable Misclosure = 24*sqrt k

Table C - Differential Leveling - Summary of Field Data

Station	BS (+) (m)	HI (m)	FS (-) (m)	Elevation (m)	Distance (m)	Adjusted Elevation
BM Sackett				353.549		353.549
	1.360	354.909			48	
TC 73			0.935	353.974	22.5	353.969
	0.655	354.629			33.8	
TC 53			2.445	352.184	34	352.179
	1.800	353.984			38.1	
TC 33			1.810	352.174	39	352.164
	1.945	354.119			18	
TP 1			0.205	353.914	21	353.904
	2.255	356.169			21	
TP 2			0.035	356.134	30.5	356.124
	0.630	356.764			20.8	
BM Old Main			0.630	356.134	20.8	356.119
Sum	8.645		6.060		347.5	

Page Check	353.549 + 8.645 - 6.060 =		356.134	ok	
Closure	BM Old Main Actual =	356.121	m		
C_{act}	356.134 - 356.121 =	0.013	m		
$C_{allowable}$	24(K (mm))^(1/2) =	24(347.5/1000)^(1/2) =		14.15	m

*Highlighted values were obtained indirectly. Unhighlighted values were directly measured.

Horizontal Distance and Angle Measurement Using the Total Station

Given: 1. Least count for this field lab = 5”
2. Smallest increment of angular measure = 2.5”

Average length of a traverse side:
1. Direct distance measurement plus reverse distance measurement.
2. The average length of the traverse side is this sum divided by two.

Adjusted angle calculations:
1. The average correction is the actual misclosure (-00°00’10”) divided by three (3), the total number of readings. The average correction is found to be +3.33”.
2. The average correction is listed as the multiple average correction.
3. This correction is then rounded to the nearest 2.5”.
4. The successive difference is then figured to the nearest 2.5” and added to the measured angle resulting in the adjusted angle.

The sum of the angles now equals 180°00’00”.

Table D - Horizontal Distance by Total Station

Backsite Station	Foresite Station	Distance (m)	Mean (m)
33	53	78.411	
33	73	113.042	113.0215
73	33	113.001	
73	53	67.441	67.4455
53	73	67.450	
53	33	78.387	78.399
Copied From Above		78.411	

Table E - Measurement of Interior Traverse					
Station	Direct Reading	Reverse Reading	Mean Angle*	Observer	Adjusted Angle
33-53	0°00'00"				
33-73	35°48'15"	71°36'10"	35°48'10"	EH	35°48'10"
73-33	0°00'00"				
73-53	42°50'05"	85°40'00"	42°50'00"	MM	42°50'00"
53-73	0°00'00"				
53-33	101°22'05"	202°43'20"	101°21'40"	MM/EH	101°21'40"
		Sum	759°59'50"		

Note: Least Count = LC = 5"
*Smallest Increment of angular measure = 2.5"
Allowable Misclosure = 1.5L.C.(n)^(1/2) = 13"
Actual Misclosure = 179°59'50" - 180°00'00"

C_{act} = -10"

Since abs(C_{act}) < C_{allow}, Survey ok

Topographic Map Details Obtained With Total Station

Given: The elevation of station TC-33 is 352.174m.
Required computations include:

$H = S(\cos\theta)$

$V = S(\sin\theta)$

$E_B = E_A + hi + V - \text{prism height}$

Sample computations using the equations above were included in the field manual, and included the following for point TC-53:

$H = S(\cos\theta)$
$= (78.426)*\cos(0°14'45")$
$= 78.4253$ m

$V = S(\sin\theta)$
$= (78.426)*\sin(0°14'45")$
$= 0.3365$ m

$E_B = E_A + hi + V - \text{prism height}$
$= 352.174 + 1.44 + 0.3365 - 1.64$
$= 352.3105$ m

Table F - Topographic Map Preparation

Total Station at TC 33 Elevation= 352.174 m hi= 1.44 m

Station	Prism Height (m)	S (m)	VA			HAR			H (m)	Elevation (m)	Description
			d	m	s	d	m	s			
TC 53	1.64	78.426	0	14	45	0	0	0	78.4253	352.3105	Traverse Point 53
TC 73	1.64	113.077	1	3	35	35	47	55	113.0577	354.0653	Traverse Point 73
1	1.64	104.352	1	14	5	41	50	5	104.3278	354.2226	Sidewalk by 73 1
2	1.64	105.256	1	5	15	37	12	50	105.2370	353.9717	Sidewalk by 73 2
3	1.64	108.363	0	58	40	34	23	35	108.3472	353.8232	Sidewalk by 73 3
4	1.64	84.493	0	28	10	12	50	30	84.4902	352.6663	Sidewalk by 53 1
5	1.64	67.674	0	37	30	6	53	40	67.6700	352.7122	Sidewalk by 53 2
6	1.64	43.560	0	58	55	357	55	20	43.5536	352.7205	Sidewalk by 53 3
7	1.64	62.172	0	28	30	359	16	5	62.1699	352.4894	33 to 53 1
8	1.64	31.223	1	34	50	357	8	15	31.2111	352.8352	33 to 53 2
9	1.64	86.941	1	25	30	35	42	55	86.9141	354.1361	33 to 73 1
10	1.64	60.746	1	54	35	35	2	5	60.7123	353.9983	33 to 73 2
11	1.64	28.417	3	3	20	33	16	50	28.3766	353.4887	33 to 73 3
12	1.64	96.050	1	15	20	36	4	0	96.0269	354.0786	Manhole
13	1.64	96.013	0	59	40	27	13	30	95.9985	353.6403	73 to 53 1
14	1.64	85.675	0	41	10	17	21	50	85.6689	352.9999	73 to 53 2
15	1.64	57.825	0	58	45	13	30	25	57.8166	352.9622	Interior Point 1
16	1.64	36.335	2	2	15	8	9	0	36.3120	353.2658	Interior Point 2
17	1.64	9.583	1	26	45	345	37	0	9.5799	352.2158	Sidewalk by 33 1
18	1.64	6.703	4	0	20	27	34	30	6.6866	352.4422	Sidewalk by 33 2
19	1.64	14.333	3	32	25	54	37	35	14.3056	352.8591	Sidewalk by 33 3

Sample Calculations:

H = S * Cos Θ = 78.426 Cos (0°14'45") = 78.4253 m --TC 73

V = S* Cos Θ = 78.426 Sin (0°14'45") = 0.336 m --TC 73

Elevation = $Elev_{33}$ + hi + V - prism height = 352.174 + 1.44 + 0.336 - 1.64 = 352.310 m

IV. Conclusions

This survey report accurately depicts the area of Old Main Lawn at Penn State University defined by markers 33, 53, and 73. Our surveys and calculations contained minimal errors, most of which are attributed to human error and miscalculation. Errors impact surveying efforts and minor preliminary errors can lead to major miscalculation in future observations. It is important to take precautions in all aspects of surveying so that early mistakes do not affect later observances. For example, if one was to make a mistake in field lab 2: Pace Calibration, anytime distance was calculated using this pace error would occur. For these reasons, it is essential to use care to minimize error in each survey.

Throughout the field labs, the only major problem that we encountered was being a short-handed group. Our original group of three including; Erin Hess, Michelle Mentzer, and Kelly Hellyer was diminished to two members when Kelly dropped the class. We offer special thanks to our teaching assistant, Dan Luther, for his patience and help in labs that were especially intensive and required a group of at least three people.

We learned many lessons in surveying that will prove invaluable as we enter into the career world. A general understanding of surveying equipment was developed. We are also now capable of assisting in surveying activities if the necessity should arise. We learned how errors impact surveying efforts and how minor preliminary errors could lead to major miscalculation in future observations. Overall, the survey experiences was very beneficial in the fact that we are able to identify surveying equipment and are able to perform basic surveying practices.

V. Appendix A – Summary of Adjustments

Table AI - Differential Leveling - Summary of Results			
Elevation Adjustments:			
STA	Measured Elevation (m)	Elevation Adjustment (m)	Adjusted Elevation (m)
TC 73	353.974	0.005	353.979
TC 53	352.184	0.005	352.189
TC 33	352.174	0.010	352.184
TP 1	353.914	0.010	353.924
TP 2	356.134	0.010	356.144

Note: Adjustments were rounded to the nearest 0.005 m.

Sample Calculation: TC 73 = +0.013(70.5/347.5) = +0.003 = +0.005 m

Table AII - Angle Corrections					
Angle	Measured Angle	Multiple Average Correction	Rounded Average Correction	Successive Difference	Adjusted Angle
33	35°48'10"	3.33	2.5	2.5	35°48'10"
73	42°50'00"	6.66	7.5	5.0	42°50'00"
53	101°21'41"	9.99	10.0	2.5	101°21'40"
					180°00'00"