Project 1

CEE 317 Section AD - Group 3

(Execution Date: October 22nd and 29th, 2015)

Buchanan, Caleb - (*Chief Assistant*)

Figueroa, Fausto - (*Chief*)

Jones, Henry - (*Rod Person, Prism Holder*)

La Rosa, Andre - (*Observer*)

Runandy, Kevin - (*Rod Person, Prism Holder*)

Williams, Malachi - (*Rod Person, Prism Holder*)

Worden, Nicholas - (*Recorder*)

November 10, 2015

Group 3
More Hall
Seattle, WA 98195

Dear Dr. Kamal Ahmed:

For this project we were tasked with three tasks to prepare a site on the University of Washington campus for the construction of a commercial high-rise building located in Sylvan Grove Theater. The goals of our tasks were to locate and stake pile locations for three pile caps, extend the control points to various locations around the perimeter of the site through the technique of traversing, and calculating the amount of earth that needs to be imported or exported to the site before construction can begin.

To accomplish these objectives, we used a total station to locate pilings based on their pile locations relative to the known line of sight from A to B. Using the same known line of sight, we then set up the total station at four points of the perimeter to establish their coordinates. Finally, we created a grid on site and elevations were measured using an automatic level to dictate cut and fill depths.

Our results include copies of our field notes for each part of the project along with data tables and computations; deliverables include our pile locations, adjusted coordinates for the traverse points, and a final amount of cut or fill.

Included in our report are project objectives, survey plans, detailed evaluations of our methods of our data and the problems encountered recording them, total angular and linear misclosure error, observed results, personnel and delegated tasks, list of equipment used, references, and computational results.

Thank you for taking the time to review this report.

Sincerely,

Buchanan, Caleb
Figueroa, Fausto
Jones, Henry
La Rosa, Andre
Runandy, Kevin
Williams, Malachi
Worden Nicholas

Table of Contents

Objectives:

Pile Locations:

The purpose of this task is to locate three pile caps (four piles per cap) before construction can drill. Measured from benchmark A, the positions of the piles were then determined and provided before and construction could begin. Locations and distances calculated relative to the line AB and benchmark A, respectively, were then located and measured by the total station. After staking all four piles for each cap, their distances relative to each other were measured to ensure their positions were within the allowed tolerance.

Traverse:

The purpose of this task is to extend the control of the project by creating new points of known coordinates. The relative angles and distances of the points that surround the whole site are used to calculate and adjust their coordinates, so they may be used as known calculated control points.

Earthwork:

The purpose of this task is to essentially level the site to allow for ease of construction. To do this, the borrow pit method was used. By creating a grid consisting of 30’x30’ spaces, elevations are measured using benchmark A so that volumes of cut and fill can be calculated.

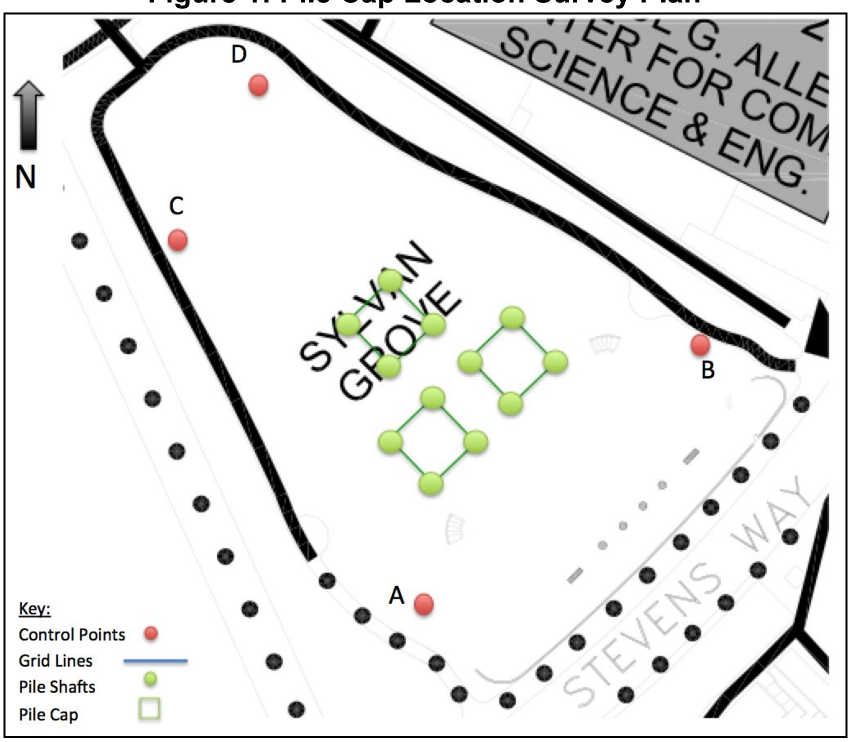
Survey Plan:

Our team's surveying project took place on the University of Washington campus in "Site 3," the Sylvan Grove Theater. The Sylvan Grove Theater is a natural outdoor theater with a gentle sloping lawn for seating and a raised lawn for a stage. None of this area is paved with the exception of the entry paths. All three tasks of pile locations, traverse and earthwork were bounded by the control points A, B, C and D.

Pile Locations:

We used the "radial method" to locate the center of the pile shafts using a total station where the angle and distance to any point within the closed traverse can easily be measured. Computing the theoretical values for distances and angles beforehand allowed us to have a numerical values to compare our measured distance between piles on. Each pile cap consists of four piles. Ideal pile shaft diameter is 3 ft with a pile spacing of 6 ft, where pile spacing is the distance from each pile axes to the other along the edges of the cap. We were given the location of the center of the cap, and the orientation of the axis A and B. Once angles were measured and pile shafts located, we measured the distance between pile shafts to obtain the pile cap perimeter lengths. No field book was used to document computed angles and distances between the piles.

Figure 1: Pile Cap Location Survey Plan



Traverse:

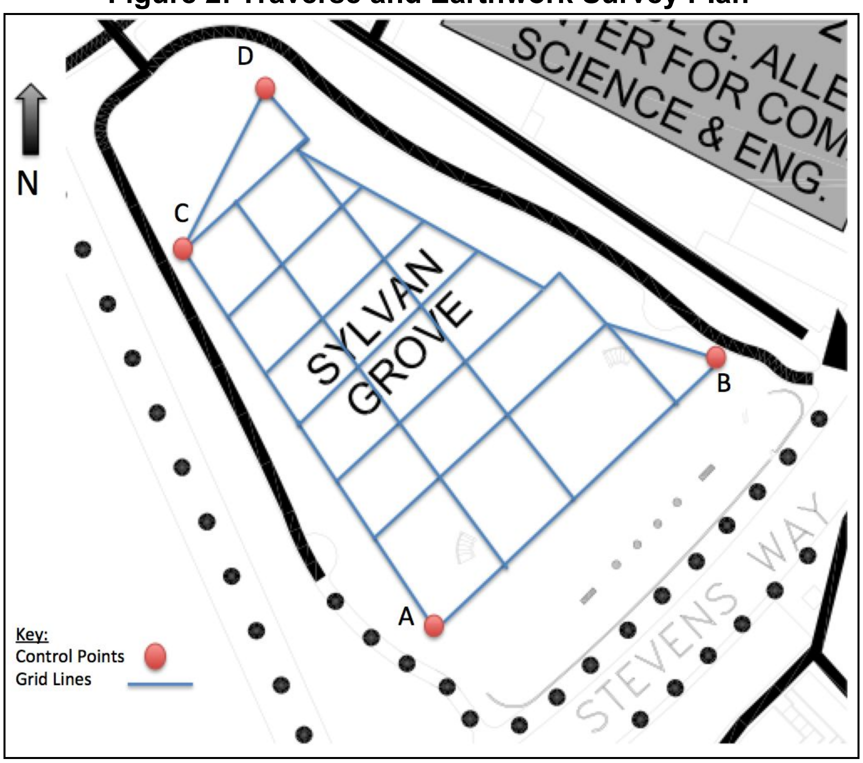
We were unable to observe the entire site from two points so more horizontal and vertical control points were needed. A traverse around the site was established and adjusted. Traverse points have to be relatively permanent. Marks were placed to define the traverse of four points for horizontal control. After adjusting the traverse, precise coordinates of the three unknown points were obtained by taking two direct readings and two reverse readings for the same angle to increase measuring accuracy. The two control points were used to compute the required azimuth to orient the traverse.

1. We decided where the three new points are needed so that control points surround the whole site, and marked the points.
2. Then, we measured the distances and the interior angles of the polygon. The azimuth of the line A-B was given, the distances were measured using the total station while angles were measured in both phases, direct and reverse, with the average as a single observation.
3. When all the measurements were completed, the traverse was adjusted and the coordinates were computed. A field notebook was used for this task.

Earthwork:

Before the construction of piles, the site must be leveled at a suitable elevation to allow safe operation of heavy equipment. In order to compute the volumes, we used the borrow-pit method. We covered the site with a grid of 30 ft spacing, placing markers along the edges at 30 ft intervals, and measured the elevation at each of the corners of the grid. After all the elevations were computed, we calculated the final amount of cut/fill. Grid lines in the figure below intersect at defined and marked elevation points.

Figure 2: Traverse and Earthwork Survey Plan



Data Acquisition:

Pile Locations:

Using the radial method and the known coordinates of point A we determined the angles and distances of 3 pile locations relative to point A using trigonometry before measurements were taken. Once these values had been computed we positioned a prism in our estimation of where one of the pile corners should be. We took distance readings with the total station and made minor adjustments using trial and error until the prism rod was directly upon the desired location. We repeated this strategy to mark out all twelve pile corners. We marked all corner locations with steel pins. Lastly, a tape measure was used to physically measure the dimensions of the staked out pile areas. These values were compared to calculated theoretical values.

Traverse:

In order to extend our controls using the traverse method we first identified the points of interest: A,B,C, and D. Points A and Azimuth AB were known. Next we placed the total station on top of point A aimed at point B and recorded the angle displayed on the screen. Then we rotated the total station counterclockwise to aim at point C and and recorded the angle displayed. Following we rotated the scope 180 degrees, aimed at Point A recorded the angle, then at point C and recorded the angle. This procedure was completed a total of three times. Finally we measured the distance from point A to B (line AB) as well as the distance from A to C (line AC) by placing the prism rod on top the A and C respectively and using the total station distance measuring function.

Next we relocated the total station on top of point C and carried out the same procedure described above to record the angle reading aiming at point A and point B, with the exception of only recording the angle values once. The distances for line CA and CB were determined using the total station and prism as described above. The same exact procedure was conducted for points C and B.

The data was collected using a field notebook and is shown below.

Table 1: Recorded Traverse Length and Angle Values

	Target	Horizontal Angle Readings		Horizontal Distances feet	Avg. Horizontal Angle	
		Direct	Reverse		Direct	Reverse
TS on A	B(AZ)	0°2'43"				
	C	270°4'1"	90°3'59"	173.12	89°58'40"	89°58'55"
	B	0°2'41"	180°2'54"	94.82		
	C	270°4'13"	90°4'22"		89°58'46"	89°59'2"
	B	0°2'59"	180°3'24"			
	C	270°4'4"	90°4'20"		89°58'50"	89°58'54"
	B	0°2'54"	180°3'14"			
				Average 1	89°58'45.3"	89°58'57"
				Average 2	89°58'51.2"	
TS on C	A	10°47'51"	190°46'47"	173.35	118°9'59"	118°9'31"
	D	252°37'52"	72°37'16"	48.03		
				Average	118°9'45"	
TS on D	C	34°30'32"	214°29'39"	47.99	76°52'46"	76°51'40
	B	317°37'46"	137°37'59	202.91		
				Average	76°52'13"	
TS on B	A	48°51'24	228°58'41"	97.79	74°59'49"	74°53'21"
	D	123°51'30	303°52'02"	202.99		
				Average	74°56'35"	

Table 2: Adjusted Traverse Coordinate and Angle Values

Line	Azimuth	Length (feet) (Averaged)	Measured Angle	Adjustment	Adjusted Angle	Departure	Latitude	Correction Departure	Correction Latitude	Adjusted Departures	Adjusted Latitudes
AB	0°2'43"	96.305	B = 74°56'35"	39"	B = 74°57'14"	0.076	96.305	0.012766657	-0.247747157	0.088766657	96.05725284
BD	254°59'18"	202.95	D = 76°52'13"	39"	D = 76°52'52"	-196.024	-52.57	0.026904035	-0.522094236	-195.997096	-53.08909424
DC	151°51'31"	48.01	C = 118°9'45"	39"	C = 118°10'24"	22.644	-42.34	0.006364438	-0.123506993	22.65036444	-42.45850699
CA	90°1'16"	173.235	A = 89°58'51.2"	39"	A = 89°59'30.2"	173.235	-0.064	0.02296487	-0.445651614	173.2579649	-0.509651614
Total		520.5	359°57'24.2"	2'36"	360°0'0.2"	-0.069	1.339	0.069	-1.339		
					Linear misclosure	1.341					

Earthwork:

We set up the total station at a point with a known elevation and created a grid of the entire area splitting up the ground into many 30ft by 30ft squares. The corners of each square were marked by flags. We placed rods at each grid corner and take an elevation reading with the total station. The sylvan theater slopes upward south to north and rods placed at the far end of the theater were too high for the total station to read so we had to move the total station to a point further north to read the rest of the corner elevations. We made sure to place the total station over a point that's elevation we had recorded earlier. The difference between the total station height and its elevation and the elevations measured were used to calculate the elevation of each corner of each 30ft by 30ft square.

Formulas: $V = \Sigma h_{ijn} \left(\frac{A}{4*27} \right) yd^3$

Table 3: Grid elevations and cut/fill depth

Point	BS	IS	FS	HI	E	Cut/Fill Depth
a1 (BM)	2.55			102.55	100	25
b1		2.63			99.92	24.92
c1		2.36			100.19	25.19
d1		2.07			100.48	25.48
e1		1.79			100.76	25.76
a2		4.28			98.27	23.27
b2		5.77			96.78	21.78
c2		3.95			98.6	23.6
d2		3.95			98.6	23.6
a3		3.88			98.67	23.67
b3		4.38			98.17	23.17
c3		4.84			97.71	22.71
d3		4.63			97.92	22.92
a4		2.32			100.23	25.23
b4		3.33			99.22	24.22
c4		3.82			98.73	23.73
a5		0.77			101.78	26.78
b5		1.56			100.99	25.99
c5	6.86		1.93	107.48	100.62	25.62
a6		4.78			102.7	27.7
b6		4.67			102.81	27.81
c6		4.06			103.42	28.42
a7		3.09			104.39	29.39
b7		3.47			104.01	29.01
c7		3.67			103.81	28.81
*	2.5		2.74	107.24	104.74	29.74
Corner		2			105.24	30.24
d6		1.47			105.77	30.77
d5		6.63			100.61	25.61
d4		8.37			98.87	23.87
d3		9.3			97.94	22.94

Data Acquisition Problems:

Pile Locations:

The main issue we encountered was communication. Due to the distance between the observer and the piles, fine-tuning to ensure precision was difficult. Prism holders relied on the observer's hand signals for direction and small adjustments were hard to account for. Recording pile locations within an acceptable tolerance yielded only slight differences between our calculated and actual readings.

Traverse:

Between point C and A, a low-hanging branch slightly obstructed the observer's vision. Because of this, personnel moved the branch during readings. In addition, the earth beneath the total station tended to be muddy, which could have resulted in total station sinking and a change in our readings.

Earthwork:

Due to the rain, the earth was quite muddy, making the level sink at times and disrupting leveling. Frequent adjustments may have created a slight inaccuracy in the readings. In addition, our site was not a perfect parallelogram; a trapezoidal section near points C and D and a triangular section along line CD needed to be calculated as part of our grid. In calculating our volumes for cut and fill, we also needed to take into consideration the section of earth near the four columns, as their distinctly higher elevation than the rest of the grid must be accounted for in calculations.

Data Adjustments:

Traverse:

Required data adjustments include adjusting the coordinates of our 4 control points. We calculated angular adjustments first.
The traverse path forms a quadrangle, and the measured angle was 359°57'24.2". Since it was below the theoretical sum of angles, the misclosure was divided equally by the number of angles, which was then added to each measured angle to satisfy the geometric total. The accuracy of the total station's readings was maintained, thus completing the process of angular adjustment and moving on to linear adjustment. Once departures and latitudes were computed we summed them individually giving us our error in the X and Y components. Using Bowditch method we took the error in the departure and latitude and divided it by the total parameter and multiplied it by each individual length of the quadrangle. This gave us the correction of each departure and latitude which in turn could be added or subtracted to the original, depending on the sign of the error, in order to give us our adjusted linear values. With linear adjustments complete, we computed the correct coordinates of each point within our traverse.

Results:

Pile Locations:

Consistent with design standards, the pile spacing is 6 feet. The measured dimensions for each pile are shown below, accompanied by diagrams.Our observed values were consistent with the theoretical values calculated within a foot (see tables and diagrams below).

Theoretical Values

Cap	a		b		c		d	
Pile	Distance (feet)	Angle	Distance (feet)	Angle	Distance (feet)	Angle	Distance	Angle
1	87.96	49°36’38”	91.97	46°45’44”	96.43	49°12’19”	92.62	52°0’59”
2	52.33	45°0’0”	56.73	40°42’39”	60.81	45°0’0”	56.73	49°17’20”
3	90.21	31°23’58”	95.38	29°31’16”	98.48	32°33’37”	93.48	34°32’24”

Observed Values

Cap	a		b		c		d	
Pile	Distance (feet)	Angle	Distance (feet)	Angle	Distance (feet)	Angle	Distance	Angle
1	87.543	49°36’38”	91.8	46°45’44”	96.54	49°12’19”	92.66	52°0’59”
2	52.28	45°0’0”	56.88	40°42’39”	60.67	45°0’0”	56.86	49°17’20”
3	90.18	31°23’58”	95.17	29°31’16”	98.31	32°33’37”	93.56	34°32’24”

Figure 3: Pile Cap # 1

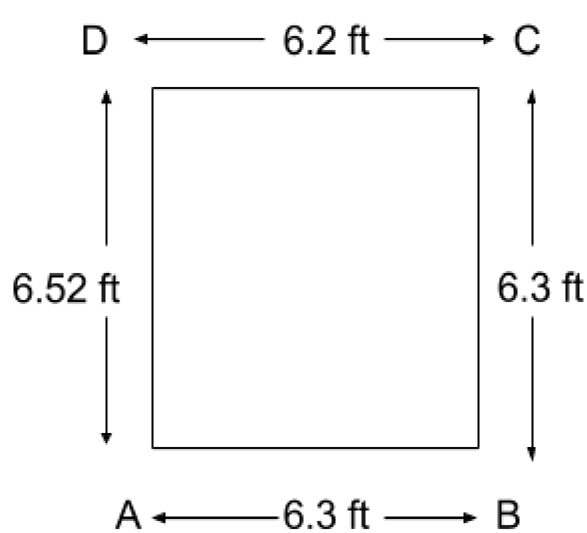


Figure 4: Pile Cap # 2

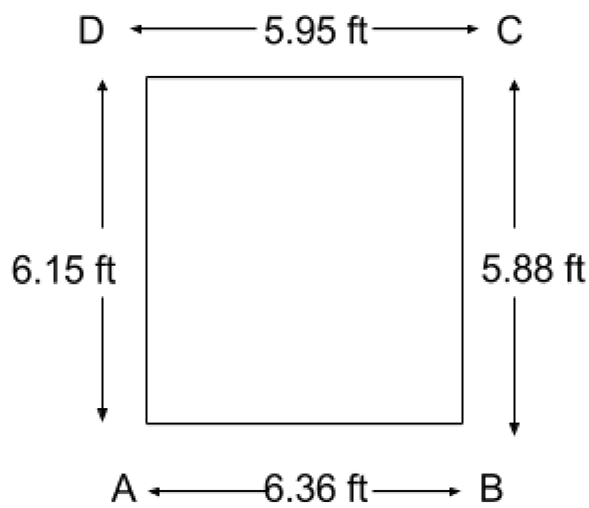
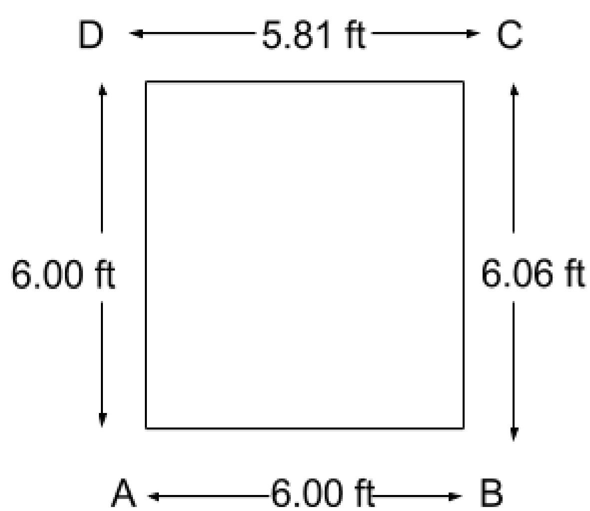


Figure 5: Pile Cap # 3



Traverse:

After performing all data adjustments, the adjusted coordinates of points A, B, D, and C rounded to the nearest foot are (1000, 1000), (1000, 1096), (804, 1043), and (827, 1001), respectively. These coordinates were calculated based on the known coordinates of point A. The total calculated angular misclosure was 0°2'35.8". The total calculated linear misclosure was 1.341 feet. All measured and adjusted values are shown below.

Earthwork:

To excavate site 3 to the desired elevation of 75 ft, it is necessary to cut and export a net volume of 14514.52 cubic yards of earth.

Personnel:

Name	**Pile Locations**	**Traverse**	**Earthwork**
Buchanan, Caleb	Asst. Chief	Asst. Chief	Asst. Chief
Figueroa, Fausto	Chief	Chief	Chief
Jones, Henry	Rod/Prism Holder	Rod/Prism Holder	Rod/Prism Holder
La Rosa, Andre	Observer	Observer	Observer
Runandy, Kevin	Rod/Prism Holder	Rod/Prism Holder	Rod/Prism Holder
Williams, Malachi	Rod/Prism Holder	Rod/Prism Holder	Rod/Prism Holder
Worden, Nicholas	Recorder	Recorder	Recorder

Equipment:

1. Total Station (Serial Number: 1293470)
2. Battery (1) (Serial Number: N/A)
3. Automatic Level (Serial Number: My4039)
4. Tripod (Serial Number: NA)
5. Umbrella (Serial Number: NA)
6. Prisms with pole (2) (Serial Number: NA)
7. Rods (2) (Serial Number: NA)
8. Walkie talkies (2) (Serial Number: NA)
9. Measuring tape (Serial Number: NA)
10. Marking pins (4) (Serial Number: NA)
11. Orange marking pins (24) (Serial Number: NA)
12. Plumb Line (Serial Number: NA)

References:

Ahmed, Dr. Kamal., “Field Note Book." *Lecture Slides*. 1-6. Microsoft PowerPoint file.

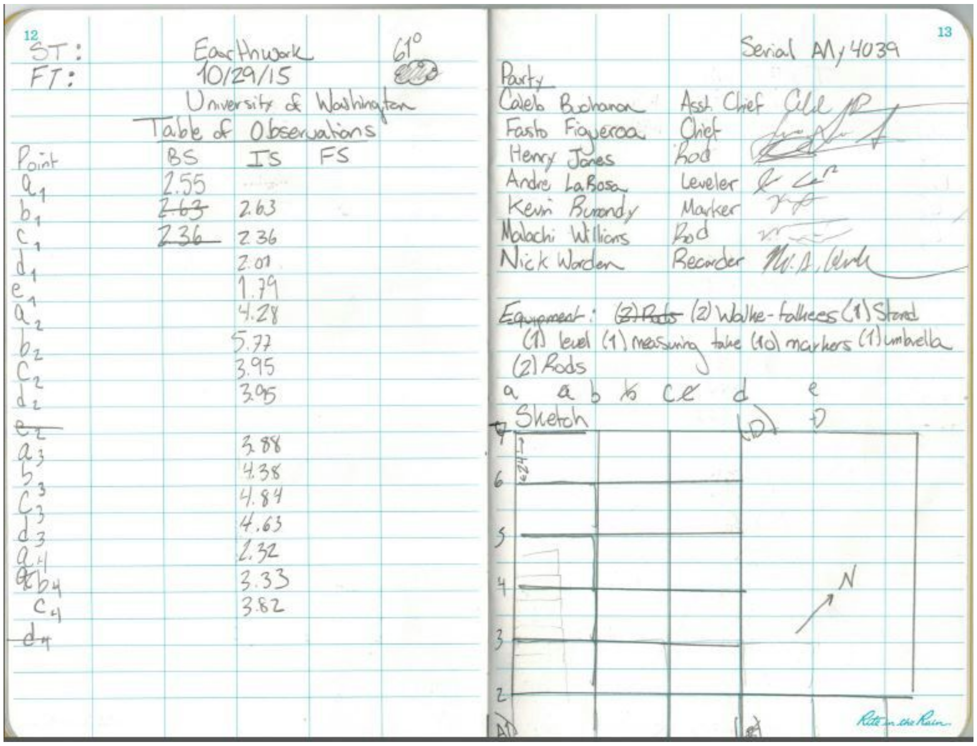
Ahmed, Dr. Kamal., “Traversing." *Lecture Slides*. 1-21. Microsoft PowerPoint file.

Ahmed, Dr. Kamal., “A Piling Construction Site." *Lab Instructions*. 1-4. PDF file.

Ghilani, Charles D., and Paul R. Wolf. *Elementary Surveying : An Introduction To Geomatics*. Upper Saddle River, N.J: Pearson Prentice Hall, 2012. Print.

University of Washington Facilities Services., “Sylvan Theatre 13-M.” *Visitor Guide*. PDF file.

Appendix A: Field Notes



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ST:
FT:

Earthwork 61°
10/29/15
University of Washington

Table of Observations

Point	BS	IS	FS
a_1	2.55		
b_1	~~2.63~~	2.63	
c_1	2.36	2.36	
d_1		2.07	
e_1		1.79	
a_2		4.28	
b_2		5.77	
c_2		3.95	
d_2		3.95	
~~e_2~~			
a_3		3.88	
b_3		4.38	
c_3		4.84	
d_3		4.63	
a_4		2.32	
b_4		3.33	
c_4		3.82	
~~d_4~~			

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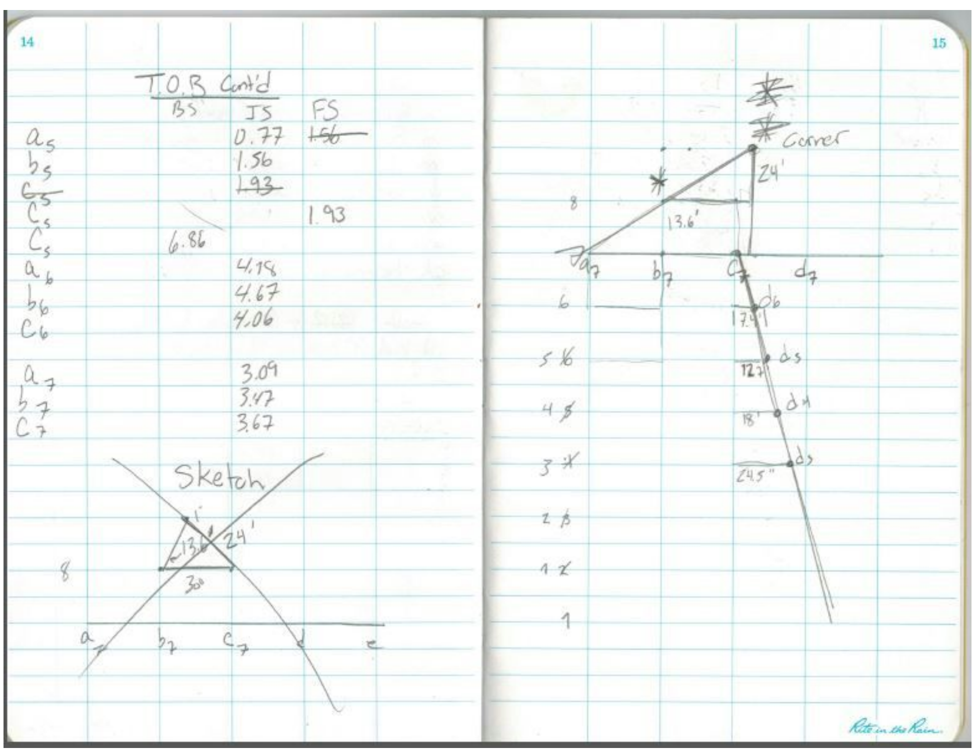
Serial AMy 4039

Party
Caleb Buchanan — Asst. Chief
Fasto Figueroa — Chief
Henry Jones — Rod
Andre LaRosa — Leveler
Kevin Burandy — Marker
Malachi Williams — Rod
Nick Warden — Recorder

Equipment: ~~(3) Rods~~ (2) Walkie-talkies (1) Stand (1) level (1) measuring tape (10) markers (1) umbrella (2) Rods

Sketch



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T.O.B. Cont'd

Point	BS	IS	FS
a_5		0.77	~~1.56~~
b_5		1.56	
~~c_5~~		~~1.93~~	
c_5			1.93
c_5	6.86		
a_6		4.18	
b_6		4.67	
c_6		4.06	
a_7		3.09	
b_7		3.47	
c_7		3.67	

Sketch

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Point	BS	IS	FS
*	2.50	~~2.47~~	2.74
Corner		2.00	
d_6		1.47	
d_5		6.63	
d_4		8.37	
d_3		9.30	

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Rite in the Rain

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ST: 1:52
FT: 2:46

Traversing
10/29/15

61°F
Rainy

University of Washington

Table of Observations
Site 3

Total Station on A   Az: $\boxed{10°2'43"}$
~~Az: 0°03'10"~~

Target	Horizontal Angle Readings: Direct	Reverse	Hor. Dist.
~~B~~C	270°4'1"	90°3'59"	173.12 ft
B	0°2'41"	180°2'54"	94.82 ft
~~B~~C	270°4'13"	90°4'22"	—
~~B~~B	0°02'59"	180°3'24"	—
C	270°4'4"	90°4'20"	—
B	0°02'54"	180°3'14"	—

Total Station at C

Target	Direct	Reverse	HD
A	10°47'51"	190°46'47"	173.35 ft
D	252°37'52"	72°37'16"	48.03 ft

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Serial #1293470

Party

Caleb Buchanan	Asst. Chief	[signature]
Fasto Figueroa	Chief	[signature]
Henry Jones	Rod holder	[signature]
Andre LaRosa	Transverser	[signature]
Kevin Runandy	Umbrella	[signature]
Malachi Williams	Measure	[signature]
Nick Worden	Recorder	Nick A. Worden

Equipment
(1) Total Station; (1) Stand; (1) Umbrella;
(2) Prisms; (2) Rods; (2) Walk-e-talkees
(1) Measuring tape

Sketch

Rite in the Rain

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T.O.B. Contd.

Target at D

Target	Direct	Reverse	H.D
C	34°30'36"	214°29'39"	47.99 ft
B	317°37'46"	137°37'59"	202.91 ft

Target at B

Target	Direct	Reverse	H.D
A	48°51'24"	228°31'41"	97.79
D	123°51'30"	303°52'02"	202.99

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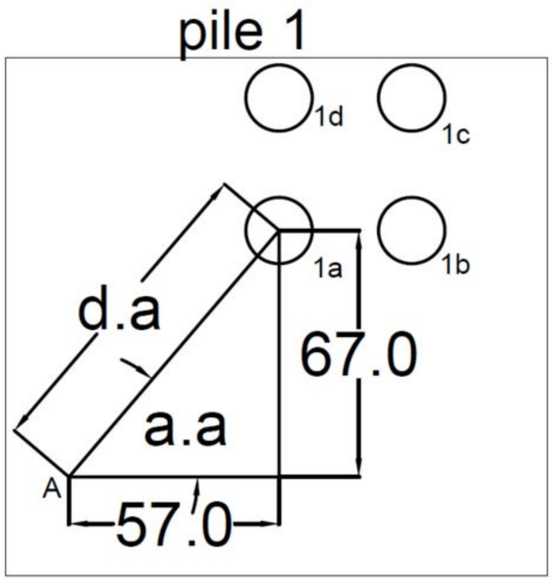
Rite in the Rain

Appendix B: Computations & Sketches

Pile Locations:



$$\alpha_a = \text{atan}\left(\frac{67}{57}\right) = 49°36'38"$$

$$d_a = \sqrt{67^2 + 47^2} = 87.96\, ft$$

Traverse:

Bowditch method

Angular misclosure

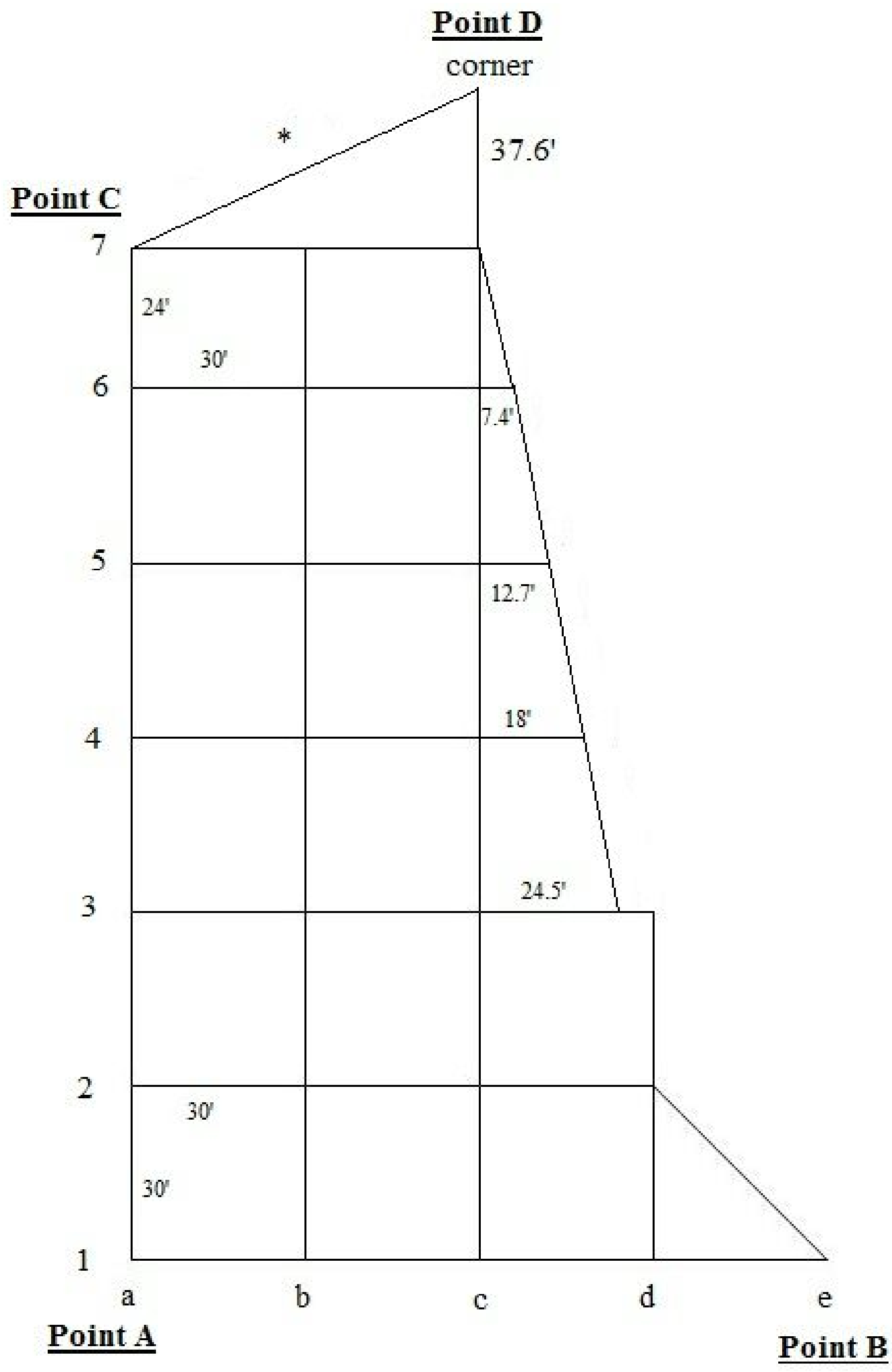
$$180(n-2) - calculated\ angle$$

$$360 - 359°57'24.2" \;=\; 0°2'35.8"$$

Linear Misclosure

$$\sqrt{W_x^2 + W_y^2} = \sqrt{.069^2 + 1.339^2} = 1.34$$

Earthwork:



Volume of cut

Volume of squares (30' x 30') =

(30 x 30) / (4 x 27) x (25(1) + 24.92(2) + 25.19(2) + 25.48(1) + 23.27(2) + 21.78(4) + 23.6(4) + 23.6(2) + 23.67(2) + 23.17(4) + 22.71(3) + 25.23(2) + 24.22(4) + 23.73(2) + 26.78(2) + 25.99(4) + 25.62(2) + 27.7(1) + 27.81(2) + 28.42(1))

= 9578.42 yd^3

Volume of squares (30’ x 24’) =
(30 x 24) / (4 x 27) x (27.7(1) + 29.39(1) + 27.81(2) + 29.01(2) + 28.42(1) + 28.81(1))
= 1519.73 yd^3

Volume of triangle a7, c7, corner =
(60 x (24 + 13.6)) / (2 x 27) x ((29.39 + 28.81 + 30.24) / 3)
= 1231.61 yd^3

Volume of triangle d1, d2, e1 =
(30 x 30) / (2 x 27) x ((25.48 + 23.6 + 25.76) / 3)
= 415.78 yd^3

Volume of triangle c6, c7, d6 =
(30 x 30) / (2 x 27) x ((28.42 + 28.81 + 30.77) / 3)
= 488.89 yd^3

Volume of trapezoid c5, c6, d6, d5 =
(((7.4 + 12.7) / 2) x 30 / 27) x ((25.62 + 28.42 + 30.77 + 25.61) / 4)
= 308.26 yd^3

Volume of trapezoid c4, c5, d5, d4 =
(((12.7+ 18) / 2) x 30 / 27) x ((23.73 + 25.62 + 25.61 + 23.87) / 4)
= 421.40 yd^3

Volume of trapezoid c3, c4, d4, d3 =
(((18 + 24.5) / 2) x 30 / 27) x ((22.71 + 23.73 + 23.87 + 22.94) / 4)
= 550.43 yd^3

Sum = 9578.42 + 1519.73 + 1231.61 + 415.78 + 488.89 + 308.26 + 421.40 + 550.43
= 14514.52 yd^3

Appendix C: Glossary

Relevant Terms and Definitions:

- Backsight: The first reading taken after setting up the level station, usually a point of calculated elevation
- Foresight: The last reading taken before removing the level, used to relate a point of unknown elevation to a point of known elevation.
- Benchmark: An established point of known elevation that is accepted to be accurate. A point used to relate to points of unknown elevations.
- Turning Point: A point from which backsights and foresights are taken from, where the rod is placed. When alternating between backsights and foresights, the rod must be rotated but not translated, so as to preserve the accuracy. Special turning points of interests are referred to as Control Points.
- Traverse: A series of consecutive lines whose ends have been marked in the field and whose lengths and directions have been determined from observations.
- Pile cap: a thick concrete mat that rests on concrete piles that have been driven into the ground.