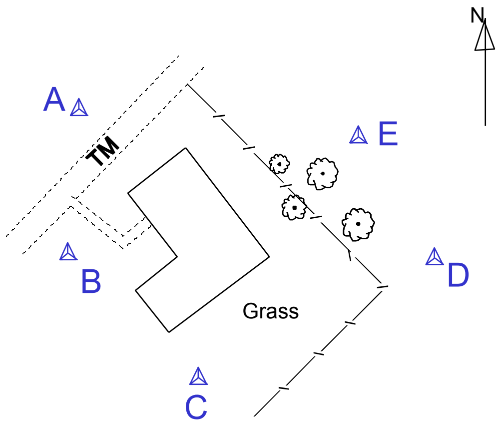
Chapter 6

TRAVERSE

Horizontal Control

- Horizontal control is required for initial survey work (detail surveys) and for setting out.

- The simplest form is a TRAVERSE - used to find out the co-ordinates of CONTROL or TRAVERSE STATIONS.



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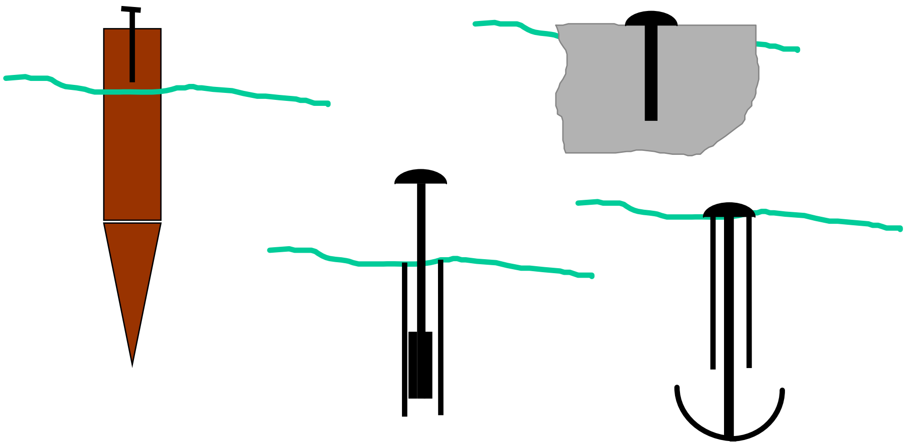


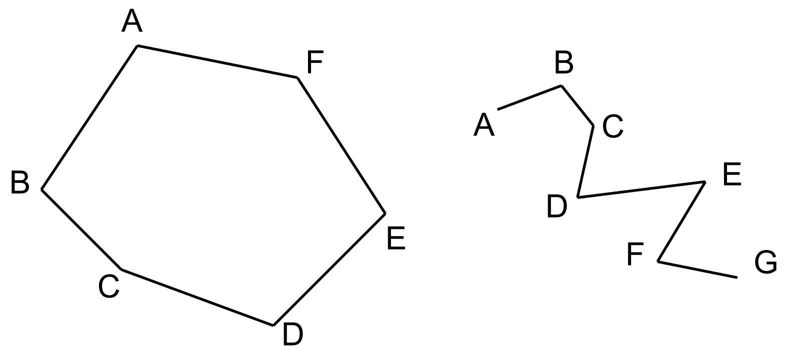
Horizontal Control

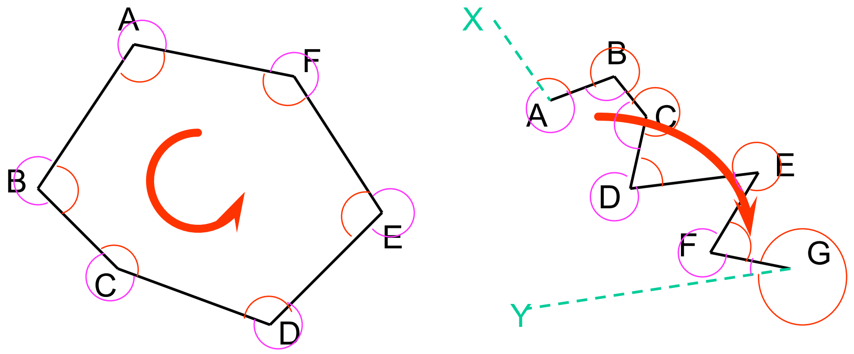
•Horizontal control is required for initial survey work (detail surveys) and for setting out.

•The simplest form is a TRAVERSE - used to find out the co-ordinates of CONTROL or TRAVERSE STATIONS.

•There are two types : - a) POLYGON or LOOP TRAVERSE

b) LINK TRAVERSE





• Both types are **closed.** a) is obviously closed

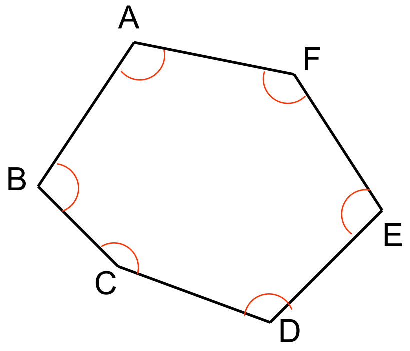
b) must start and finish at points whose co-ordinates are known,

and must also start and finish with angle observations to other known points.

• Working in the direction A to B to C etc is the **FORWARD DIRECTION**

• This gives two possible angles at each station.

LEFT HAND ANGLES **RIGHT HAND ANGLES**



Consider the **POLYGON** traverse

The **L.H.Angles** are also the **INTERNAL ANGLES**

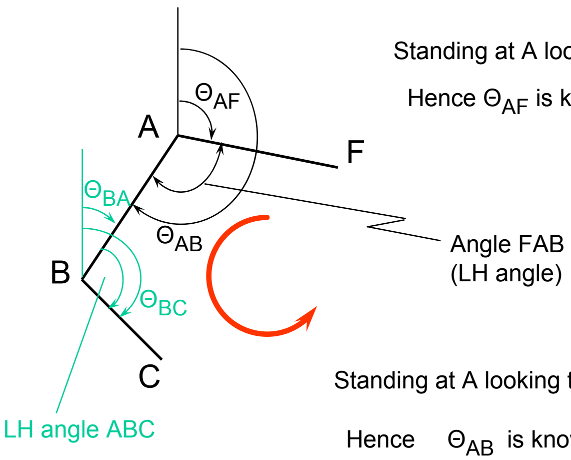
Using a theodolite we can measure all the internal angles.

Σ (Internal Angles) = (2 N - 4) * 90^0

The difference between Σ Measured Angles and Σ Internal Angles is the Angular Misclosure

Maximum Angular Misclosure = 2 (or 3) * Accuracy of Theodolite * √ (No. of Angles)

(Rule of thumb)



Standing at A looking towards F - looking **BACK**

Hence Θ_{AF} is known as a **Azimuth**

Standing at A looking towards B - looking **FORWARD**

Hence Θ_{AB} is known as a **FORWARD Azimuth**

BACK Azimuth (Θ_{AF}) + L.H.ANGLE (<FAB) = NEXT FORWARD Azimuth (Θ_{AB})

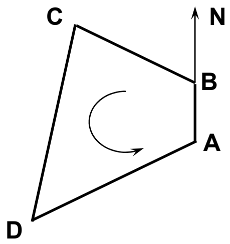
Reminder: every line has two bearings

BACK Azimuth (Θ_{BA}) = FORWARD Azimuth (Θ_{AB}) $\pm$ 180^0

Traverse Example

12" / 4 = 3"

Observations, using a Zeiss O15B, 6" Theodolite, were taken in the field for an anti - clockwise polygon traverse, A, B, C, D.



Traverse Station	Observed Clockwise Horizontal Angle (° ' ")
A	132 15 30 - 3"
B	126 12 54 - 3"
C	69 41 18 - 3"
D	31 50 30 - 3"

Line	Horizontal Distance
AB	638.57
BC	1576.20
CD	3824.10
DA	3133.72

Σ (Internal Angles) = 360 00 12

Σ (Internal Angles) should be (2N-4)*90 = 360 00 00

Allowable = 3 * 6" * √N= 36"

OK - Therefore distribute error

The bearing of line AB is to be assumed to be 0^0 and the co-ordinates of station A are (3000.00 mE ; 4000.00 mN)

LINE / STATION / LINE		BACK BEARING / ADJUSTED LEFT HAND ANGLE + / FORWARD BEARING = Check 1			WHOLE CIRCLE BEARING			HORIZONTAL DISTANCE
AD		227	44	33				
A		132	15 ✓	27				
AB	+or-	00	00	00	00	00	00	638.57
BA	180°	180	00	00				
B		126	12	51				
BC	+or-	306	12	51	306	12	51	1576.20
CB	180°	126	12	51				
C		69	41	15				
CD	+or-	195	54	06	195	54	06	3824.10
DC	180°	15	54	06				
D		31	50	27				
DA		47	44	33	47	44	33	3133.72
AD		227	44	33				

Use Distance and Bearing to go from POLAR to RECTANGULAR to get Delta E and Delta N values.

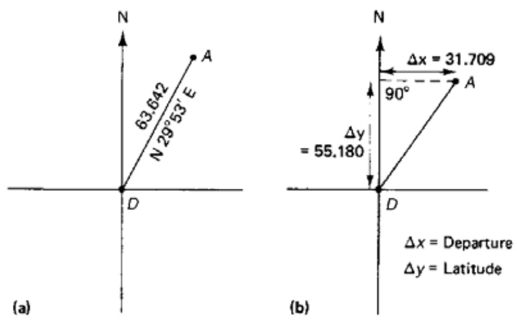
LATITUDES AND DEPARTURES

FIGURE 6.5:

LOCATION OF A POINT.

A)POLAR TIES

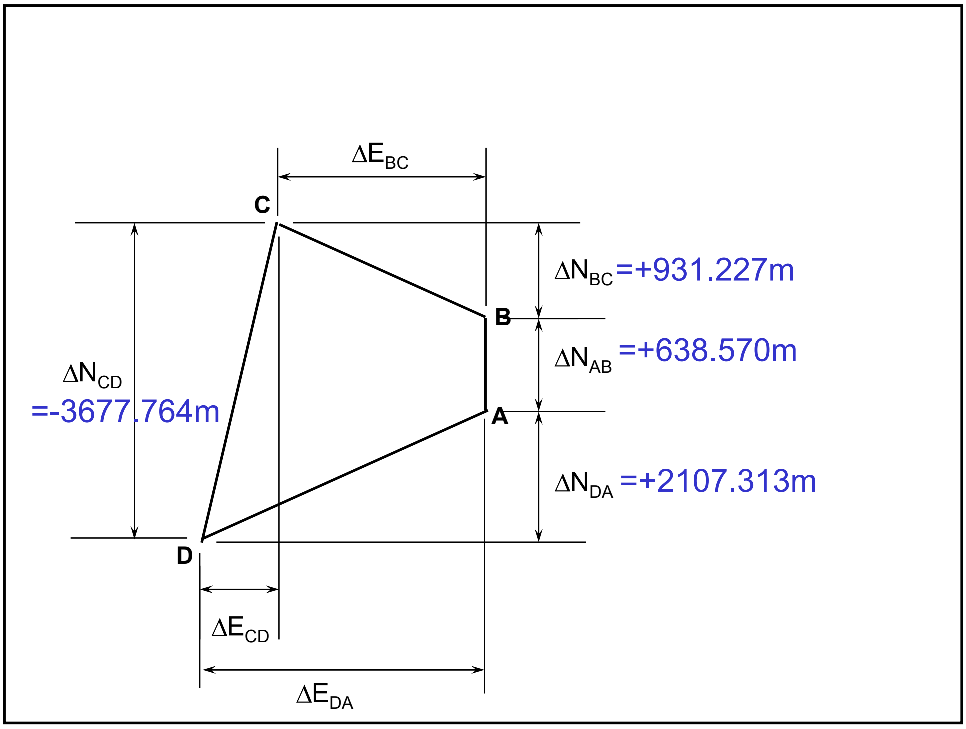
B)RECTANGULAR TIES



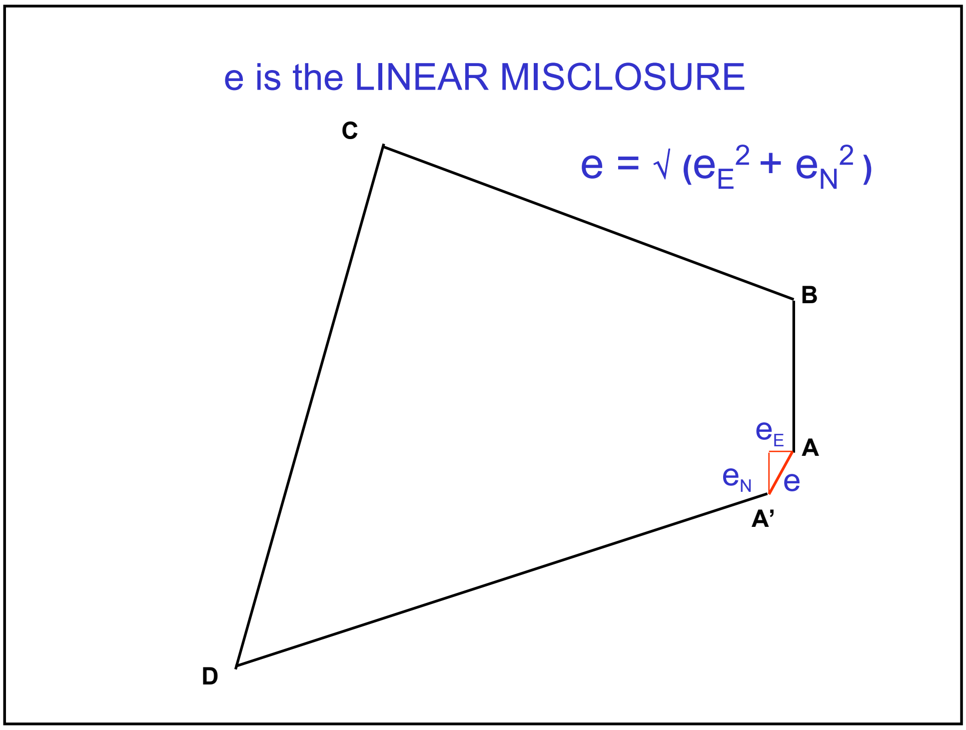
LATITUDE = NORTH(+) SOUTH (-)=distance(H) x cosα

DEPARTURE = EAST(+) WEST (-)= distance(H) x sinα

WHOLE CIRCLE BEARING θ			HORIZONTAL DISTANCE D	CO-ORDINATE DIFFERENCES CALCULATED	
				Δ E	Δ N
00	00	00	638.57	0.000	+638.570
306	12	51	1576.10	-1271.701	+931.227
195	54	06	3824.10	-1047.754	-3677.764
47	44	33	3133.72	+2319.361	+2107.313
				-0.094	-0.654



ΔE_BC
C
ΔN_BC =+931.227m
B
ΔN_AB =+638.570m
ΔN_CD
=-3677.764m
A
ΔN_DA =+2107.313m
D
ΔE_CD
ΔE_DA



e is the LINEAR MISCLOSURE
C
$e = \sqrt{(e_E^2 + e_N^2)}$
B
e_E
A
e_N
e
A'
D

WHOLE CIRCLE BEARING θ			HORIZONTAL DISTANCE D	CO-ORDINATE DIFFERENCES CALCULATED ΔE	ΔN
00	00	00	638.57	0.000	+638.570
306	12	51	1576.10	-1271.701	+931.227
195	54	06	3824.10	-1047.754	-3677.764
47	44	33	3133.72	+2319.361	+2107.313
		☝	9172.59 ☝	-0.094 e_E	-0.654 e_N

$e = \sqrt{(e_E^2 + e_N^2)} = \sqrt{(0.094^2 + 0.654^2)} = 0.661m$

Fractional Linear Misclosure (FLM) = 1 in ☝ D / e

= 1 in (9172.59 / 0.661) = 1 in 13500

[To the nearest 500 lower value]

Acceptable FLM values :-

- 1 in 5000 — for most engineering surveys
- 1 in 10000 — for control for large projects
- 1 in 20000 — for major works and monitoring for structural deformation etc.

WHOLE CIRCLE BEARING θ			HORIZONTAL DISTANCE D	CO-ORDINATE DIFFERENCES CALCULATED ΔE	ΔN
00	00	00	638.57	0.000	+638.570
306	12	51	1576.10	-1271.701	+931.227
195	54	06	3824.10	-1047.754	-3677.764
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		☝	9172.59 ☝	-0.094 e_E	-0.654 e_N

$e = \sqrt{(e_E^2 + e_N^2)} = \sqrt{(0.094^2 + 0.654^2)} = 0.661m$

Fractional Linear Misclosure (FLM) = 1 in ☝ D / e

= 1 in (9172.59 / 0.661) = 1 in 13500 ✓ Check 2

If not acceptable ie 1 in 3500 then we have an error in fieldwork

If the misclosure is acceptable then distribute it by: -

a) Bowditch Method - proportional to line distances

b) Transit Method - proportional to ΔE and ΔN values

c) Numerous other methods including Least Squares Adjustments

a) Bowditch Method - proportional to line distances

The e_E and the e_N have to be distributed

For any line IJ the adjustments are δE_{IJ} and δN_{IJ}

$\delta E_{IJ} = [\, e_E / \sum D \,] \times D_{IJ}$ *Applied with the opposite sign to e_E*

$\delta N_{IJ} = [\, e_N / \sum D \,] \times D_{IJ}$ *Applied with the opposite sign to e_N*

WHOLE CIRCLE BEARING θ			HORIZONTAL DISTANCE D	CO-ORDINATE DIFFERENCES CALCULATED	
				Δ E	Δ N
00	00	00	638.57	0.000	+638.570
306	12	51	1576.20	-1271.701	+931.227
195	54	06	3824.10	-1047.754	-3677.764
47	44	33	3133.72	+2319.361	+2107.313
			9172.59	-0.094 e_E	-0.654 e_N

$e = \sqrt{(e_E^2 + e_N^2)} = \sqrt{(0.094^2 + 0.654^2)} = 0.661$m

Fractional Linear Misclosure (FLM) = 1 in $\sum D / e$

= 1 in 9172.59 / 0.661 = 1 in 13500 ✓ **Check 2**

$\delta E_{IJ} = [\, e_E / \Sigma D \,] \times D_{IJ}$

Applied with the opposite sign to e_E

$e_E = -0.094m$ $\quad\quad \Sigma D = 9172.59$ m

$\delta E_{IJ} = [+0.094 / 9172.59\,] \times D_{IJ} = +0.0000102479\ldots\ldots \times D_{IJ}$

Store this in the memory

For line AB

$\delta E_{AB} = +0.0000102479\ldots \times D_{AB} = +0.0000102479\ldots \times 638.57$

$\delta E_{AB} = +0.007m$

For line BC

$\delta E_{BC} = +0.0000102479\ldots \times D_{BC} = +0.0000102479\ldots \times 1576.20$

$\delta E_{BC} = +0.016m$

For line CD

$\delta E_{CD} = +0.039m$

For line DA

$\delta E_{DA} = +0.032m$

CO-ORDINATE DIFFERENCES						CO-ORDINATES		STATION
CALCULATED		ADJUSTMENTS		ADJUSTED				
ΔE	ΔN	δE	δN	ΔE	ΔN	E	N	
0.000	+638.570	+0.007						
-1271.701	+931.227	+0.016						
-1047.754	-3677.764	+0.039						
+2319.361	+2107.313	+0.032						
-0.094 e_E	-0.654 e_N							

$\delta N_{IJ} = [\, e_N / \Sigma D \,] \times D_{IJ}$ *Applied with the opposite sign to e_N*

$e_N = -0.654m$

$\delta N_{IJ} = [+0.654 / 9172.59] \times D_{IJ} = +0.000071299\ldots\ldots \times D_{IJ}$

Store this in the memory

$\delta N_{AB} = +\ 0.000071299\ldots \times D_{AB} = +\ 0.000071299\ldots \times 638.57$

$\delta N_{AB} = +0.046m$

$\delta N_{BC} = +0.112m$

$\delta N_{CD} = +0.273m$

$\delta N_{DA} = +0.223m$

CO-ORDINATE DIFFERENCES						CO-ORDINATES		STATION
CALCULATED		ADJUSTMENTS		ADJUSTED				
ΔE	ΔN	δE	δN	ΔE	ΔN	E	N	
						3000.00	4000.00	A
0.000	+638.570	+0.007	+0.046	+0.007	+638.616	3000.01	4638.62	B
-1271.701	+931.227	+0.016	+0.112	-1271.685	+931.339	1728.32	5569.96	C
-1047.754	-3677.764	+0.039	+0.273	-1047.715	-3677.491	680.61	1892.46	D
+2319.361	+2107.313	+0.032	+0.223	+2319.393	+2107.536	3000.00 ✓	4000.00 ✓	A
-0.094 e_E	-0.654 e_N			$\Sigma = 0$	$\Sigma = 0$	Check 3		

6.13 SUMMARY OF TRAVERSE COMPUTATIONS

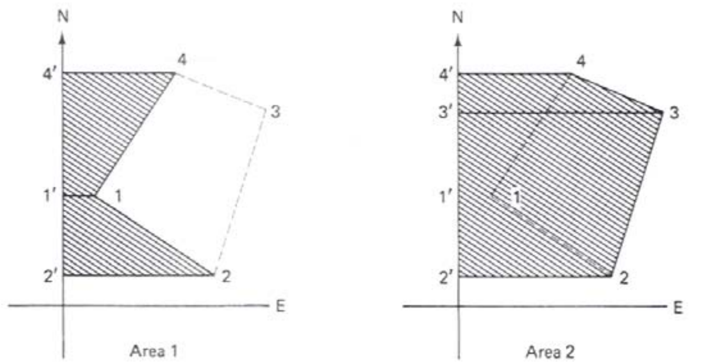
1. Balance the field angles (1st step)
2. Correct (if necessary) the field distances (2nd step)
3. Compute the bearings and/or azimuths (3rd step)
4. Compute the linear error of closure and the precision ratio of the traverse (4th step)
5. Compute the balances latitudes (Δy) and balanced departures (Δx) (5th step)
6. Compute coordinates (6th step)
7. Compute the area (7th step)

6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE METHOD

The double area of a closed traverse is the algebraic sum of each X coordinate by the difference between the Y values of the adjacent stations.

The final area can result in a positive or negative number, reflecting only the direction of computation (either clockwise or anti clockwise). However there area is POSITIVE…THERE ARE NO NEGATIVE AREAS.

6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE METHOD



Area 2 − Area 1 = Area of Traverse

(b)

area of the traverse is, in effect, area 2 minus area 1

$$\text{Area 2} = \tfrac{1}{2}(X_4 + X_3)(Y_4 - Y_3) + \tfrac{1}{2}(X_3 + X_2)(Y_3 - Y_2)$$

$$\text{Area} = \tfrac{1}{2}(X_4 + X_1)(Y_4 - Y_1) + \tfrac{1}{2}(X_1 + X_2)(Y_1 - Y_2)$$

$$2A = [(X_4 + X_3)(Y_4 - Y_3) + (X_3 + X_2)(Y_3 - Y_2)] - [(X_4 + X_1)(Y_4 + X_1)(Y_4 - Y_1) + (X_1 + X_2)(Y_1 - Y_2)]$$

$$2A = X_1(Y_2 - Y_4) + X_2(Y_3 - Y_1) + X_3(Y_4 - Y_2) + X_4(Y_1 - Y_3)$$

Stated simply, **the double area of a closed traverse is the algebraic sum of each X coordinate multiplied by the difference between the Y values of the adjacent stations.**

■ EXAMPLE 6.4

Area Computation by Coordinates

Refer to the traverse example in Example 6.3, and the computed coordinates shown in Figure 6.18, which are summarized next:

STATION	NORTH	EAST
A	1,089.981	935.049
B	1,000.000	1,000.000
C	1,078.754	1,068.139
D	1,046.635	1,205.498
E	1,154.366	1,030.252

$$2A = X_1(Y_2 - Y_4) + X_2(Y_3 - Y_1) + X_3(Y_4 - Y_2) + X_4(Y_1 - Y_3)$$

Solution

The **double area computation** (to the closest m^2) is:

$$XA(YB - YE) = 935.049(1,000.000 - 1,154.366) = -144,340$$

$$XB(YC - YA) = 1,000.000(1,078.754 - 1,089.981) = -11,227$$
$$XC(YD - YB) = 1,068.139(1,046.635 - 1,000.000) = +49,813$$
$$XD(YE - YC) = 1,205.498(1,154.366 - 1,078.754) = +91,150$$
$$XE(YA - YD) = 1,030.252(1,089.981 - 1,046.635) = \underline{+44,657}$$
$$2A = +30,053 \text{ m}^2$$

$$\text{Area} = 15,027 \text{ m}^2$$
$$= 1.503 \text{ hectares}$$

6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE

■ EXAMPLE 6.5

Area Computation by Coordinates

Refer to the traverse example in Section 6.6 and to Figures 6.15 and 6.22. The coordinates are summarized next:

STATION	NORTH	EAST
A	1,000.00 ft	1,000.00 ft
B	1,250.73	1,313.61
C	1,302.96	1,692.14
D	934.77	1,684.54
E	688.69	1,160.27

Solution

The double area computation (to the closest ft^2), using the relationships shown in Equation 6.7, is:

$$2A = X_1(Y_2 - Y_4) + X_2(Y_3 - Y_1) + X_3(Y_4 - Y_2) + X_4(Y_1 - Y_3)$$

$$XA(YB - YE) = 1,000.00(1,250.73 - 688.69) = +562,040$$
$$XB(YC - YA) = 1,313.61(1,302.96 - 1,000.00) = +397,971$$
$$XC(YD - YB) = 1,692.14(934.77 - 1,250.73) = -534,649$$
$$XD(YE - YC) = 1,684.54(688.69 - 1,302.96) = -1,034,762$$
$$XE(YA - YD) = 1,160.27(1,000.00 - 934.77) = \underline{+75,684}$$
$$-533,716 \text{ ft}^2$$
$$2A = 533,716 \text{ ft}^2$$

$$\text{Area} = 266,858 \text{ ft}^2$$

Also:

$$\text{Area} = \frac{246,858}{43,560} = 6.126 \text{ acres} \qquad (1 \text{ acre} = 43,560 \text{ ft}^2)$$

END OF CHAPTER 6

THANK YOU FOR YOUR ATTENTION