

**Poulton** *Research Project*

# The Poulton Survey Control Network

by

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The Poulton Research Project is an independent archaeology research project, based around the remains of a Cistercian Abbey at Poulton, Cheshire (between Chester and Wrexham). Established in 1995, it provides numerous students, volunteers and young people from the local community with the opportunity to participate in hands-on archaeology and historical investigation. The Project is closely associated with West Cheshire College as part of their community education programme, and several classes have been taught at the Poulton site. The general public is welcomed to the site on open days, and the Project has featured on TV including BBC's 'Meet The Ancestors' programme.

The Poulton Research Project is a registered charity, (registration number 1094552) with the stated aim 'To further the education of the public in the archaeology, history and architecture of a multi-period landscape in the Chester hinterland known as The Poulton Project and to promote and foster public knowledge, understanding and appreciation of Archaeology generally'.

So far the Project has uncovered finds and other evidence for human occupation at the site, extending from the Stone Age (at least 5000 BC) through Roman, Saxon and medieval periods to the English Civil War, right up to a 20th century airfield.

More details of the Poulton Research Project can be found on its website at <http://srs.dl.ac.uk/arch/poulton/index.shtml>.

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Our sincere thanks are due to Sokkia Ltd., for the long-term loan of surveying equipment.

## 1. Introduction

The main Poulton site grid, known as the Trench I grid, was established when work first started in 1995. It has an arbitrary origin and orientation, being aligned with the hedge immediately to the South of the chapel where excavation first started [Emery *et al.*, 1996]. As is typical for an archaeological site, the grid was physically defined by markers (usually sections of steel reinforcing bar) placed at 5m intervals across the area being investigated.

Since those early days of the Project, archaeological investigations have spread over a much wider area of the surrounding landscape. Unfortunately, when a new major trench (Trench XVI) was opened across a ring ditch some 100 m away from Trench I, another arbitrary local grid was established. This is known as the Ring Ditch grid.

One of the drawbacks of these types of grid is that all the markers are vulnerable to accidental or deliberate damage and are unlikely to survive in the longer term (as already demonstrated by the backfilling of part of Trench I). This will make it difficult to re-locate key features (e.g. trench corners or special finds) at a future date. Furthermore, it is not possible to relate the features discovered at Poulton (e.g. roads and trackways) to other features in the wider landscape, as shown on maps.

In order to overcome these problems, work was carried out during 2003 and 2004 with the following aims:

- To establish a robust and permanent control network at Poulton, covering as wide an area as possible.
- To determine the precise relationship between the two existing local grids.
- To establish the precise relationship between the local grids and the OS National Grid.

Section 2 of this report describes how the control network was established, while Section 3 shows how to convert coordinates between the Trench I and Ring Ditch systems. Section 4 assesses the accuracy which can be achieved in determining National Grid coordinates using the Global Positioning System (GPS) and Section 5 shows how to convert coordinates between the Trench I and National Grid systems.

## 2. Network Observation and Adjustment

The first task was to establish 15 control stations across the Poulton site. Where possible, these stations were based on well-established physical features, although this was difficult to achieve in the rural environment. Detailed descriptions of the individual stations are given in Appendix 7, while a map showing the stations and the main physical features of the site is shown below.

The second step was to determine the local coordinates of one control station within each of the two main trenches (Trench I and Ring Ditch), by taking measure-

ments to several of the existing trench grid markers (Section 2.1). Finally, the entire control network was observed and adjusted (Section 2.2).

All observations were carried out between July and September 2003, using a Sokkia SET 3BII total station. All observations (horizontal angle, horizontal distance and height difference) were repeated on face left and face right, then averaged.

### 2.1 Control Stations in Trench I and Ring Ditch trench

Within the two main trenches (Trench I and Ring Ditch), there are control stations known respectively as TR1 TBM and Ring Ditch. The horizontal coordinates of these points in their local trench reference systems were determined by setting up the instrument over the control station and observing to several of the existing trench grid markers. These markers were treated as fixed points in a least squares adjustment, performed using the EasyNet 2.4 package from Yuanda IT Services [Yuanda, 2003]. In each case, the instrument was orientated on a distant control station (Ramp), so that the adjustment also defined the bearing of the corresponding line in the local grid system.

*A priori* standard errors were determined using the following data:

- Station centring error: 10 mm
- Target centring error: 20 mm
- Distance measurement: 5 mm + 5 ppm
- Direction measurement: 5"

(**N.B.** At the short ranges in these networks, the centring errors are the predominant factor).

For both control stations, the *a posteriori* standard errors of the adjusted coordinates were between 1 and 2 cm. The detailed adjustment reports are in Appendices 1 and 2.

The height of TR1 TBM was already known since this is the primary site TBM, while the height of Ring Ditch was determined both by spirit levelling and using the control network - see Section 2.4.

### 2.2 Control Network

The observations were adjusted by least squares using the 'Adjust for Windows' package developed at Penn State University [PSU, 2003]. Horizontal and vertical observations were adjusted separately (Sections 2.3 and 2.4 respectively). The reference system used for the horizontal adjustment was the Trench I coordinate system.

Station Geophys 4 was excluded from the adjustments as it was removed while the observations were being made.

### 2.3 Horizontal Adjustment

The network was initially adjusted using just the angle ob-

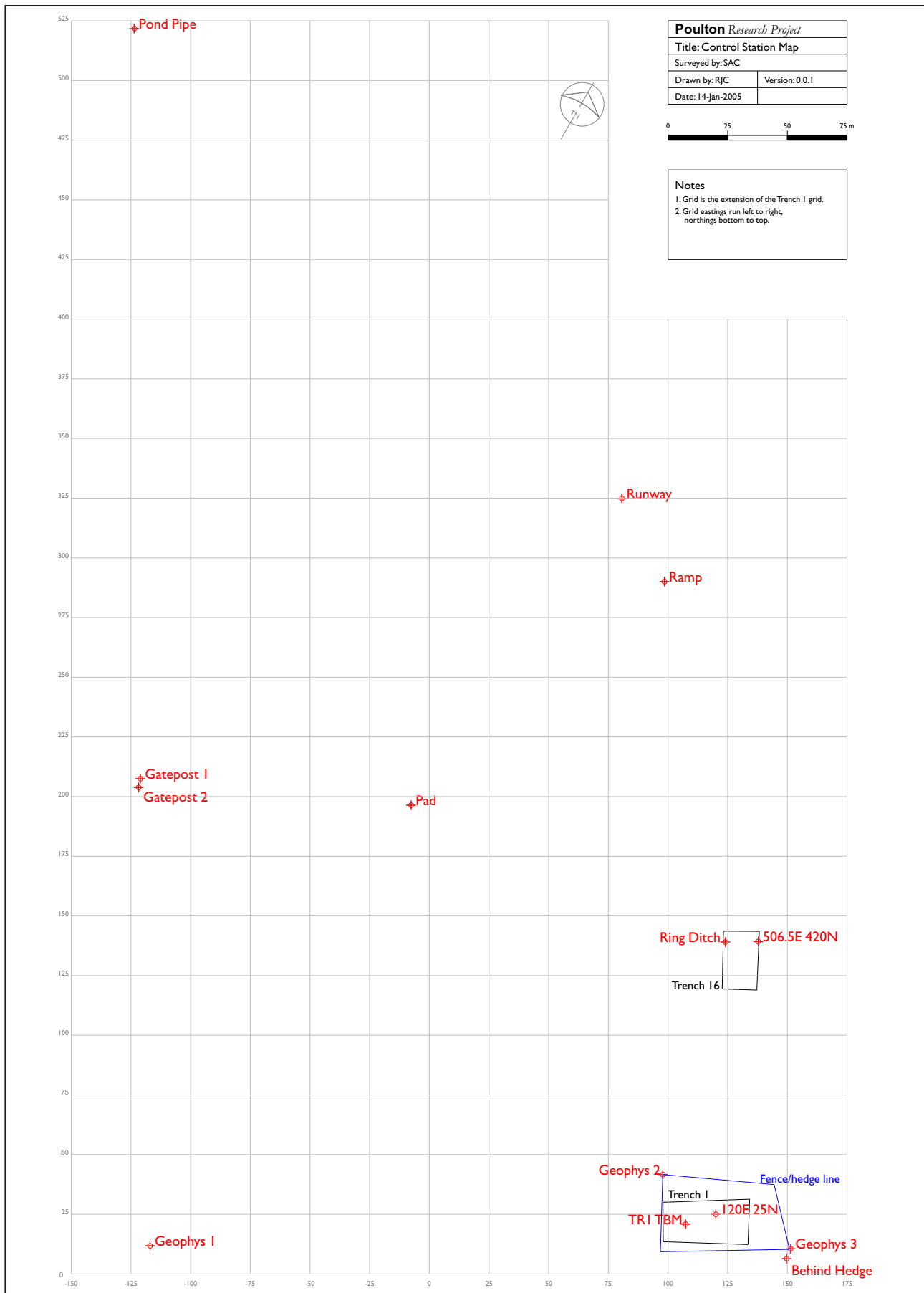


Figure 1 - Location of Poulton Control Stations

servations, plus:

- One arbitrary distance
- One fixed point (TR1 TBM - set to the coordinates calculated as described in Section 2.1)
- One fixed azimuth (TR1 TBM to Ramp - set to the bearing calculated as described in Section 2.1)

(**N.B.** Stations Geophys 3 and Gatepost 1, together with the corresponding observations, were omitted at this stage since the angle observations on their own were insufficient to fix their positions).

The *a priori* standard errors of the angle observations were corrected until the unit variance ( $\sigma^2$ ) was approximately equal to 1.

The distance observations (plus the angle observations to Geophys 3 and Gatepost 1) were then added and the *a priori* standard errors of the distances corrected until the unit variance was again approximately equal to 1.

The resulting *a priori* standard errors were as follows:

- Station centring error: 5 mm
- Target centring error: 15 mm
- Distance measurement: 5 mm + 5 ppm
- Direction measurement: 5"

The maximum *a posteriori* standard errors of the adjusted coordinates were less than 3 cm, except for those points where the observation geometry was particularly unfavourable (e.g. Behind Hedge and Geophys 3, both of which could only be observed from single points).

(**N.B.** The figures shown in the adjustment report are twice the standard error, representing the 95% confidence level.)

The detailed adjustment report is in Appendix 3 and a diagram of the network showing error ellipses is in Appendix 4. The resulting coordinates are summarised in Appendix 6.

## 2.4 Vertical Adjustment

The height of TR1 TBM was held fixed at its known value. *A priori* standard errors were assigned in proportion to distance.

The *a posteriori* standard errors of the adjusted heights were all less than 1 cm. The heights of the Ring Ditch control station determined by spirit levelling (on the one hand) and from the network adjustment (on the other hand) agreed to within a centimetre.

The detailed adjustment report is in Appendix 5 and the resulting heights are summarised in Appendix 6.

## 3. Transformations between Trench I and Ring Ditch Coordinate Systems

Three-parameter transformations (a rotation + 2 shifts) were calculated between the Trench I and Ring Ditch coordinate systems, in both directions. The data used were the coordinates of the points Ring Ditch and 506.5E

420N, which were known in both systems. The transformations were calculated using the LISCAD 6.1 software from Listech [Listech, 2003]. The mean absolute difference between the coordinates in one system and the corresponding transformed coordinates from the other system is 3 mm.

### 3.1 From Trench I system (TR1) to Ring Ditch system (RD)

$$E_{RD} = (0.99405000 \times E_{TR1}) - (0.10892471 \times N_{TR1}) + 384.698$$

$$N_{RD} = (0.10892471 \times E_{TR1}) + (0.99405000 \times N_{TR1}) + 266.551$$

**Example:** Ring Ditch peg has coordinates in TR1 system of 124.021E, 139.061N. Coordinates in RD system are as follows:

$$E_{RD} = (0.99405000 \times 124.021) - (0.10892471 \times 139.061) + 384.698 = 492.834$$

$$N_{RD} = (0.10892471 \times 124.021) + (0.99405000 \times 139.061) + 266.551 = 418.294$$

### 3.2 From Ring Ditch system (RD) to Trench I system (TR1)

$$E_{TR1} = (0.99405000 \times E_{RD}) + (0.10892471 \times N_{RD}) - 411.443$$

$$N_{TR1} = (-0.10892471 \times E_{RD}) + (0.99405000 \times N_{RD}) - 223.063$$

**Example:** Grid pin in Ring Ditch trench has coordinates in RD system of 506.5E, 420N. Coordinates in TR1 system are as follows:

$$E_{TR1} = (0.99405000 \times 506.5) + (0.10892471 \times 420) - 411.443 = 137.792$$

$$N_{TR1} = (-0.10892471 \times 506.5) + (0.99405000 \times 420) - 223.063 = 139.268$$

## 4. Relationship of Poulton Local Coordinate System to OS National Grid

An exercise was undertaken in 2004 to relate the Poulton Trench I coordinate system to the Ordnance Survey National Grid, which provides a well-defined and generally-accepted reference framework for the whole of Great Britain. This exercise had two main aims:

- To determine the best technique for measuring the National Grid coordinates of points at Poulton, taking into account:
  - Probable future requirements to link in remote parts of the site (e.g. the 'Roman Road');
  - The accuracy required for archaeological purposes (0.5 m or better); and
  - The costs involved (like most archaeological organisations, Poulton has very little money!).
- To compute transformation parameters between the

Trench I coordinate system and the National Grid (in both directions). These parameters would consist of a shift (2-D) and rotation, plus a fixed scale factor to account for the National Grid local scale factor [Ordnance Survey, 1950].

**4.1 Method and Equipment**

GPS is the obvious choice of technique, particularly as the National Grid is now itself defined in terms of a network of GPS stations rather than the traditional trig pillars. Until recently, achieving sub-metre accuracies would have required equipment costing thousands of pounds. However, it has been claimed that positioning accuracies of around 20 cm can be achieved using much less expensive equipment, i.e. a Garmin 12-channel GPS receiver together with the GRINGO/P4 software, together costing under £250 [Ordnance Survey, 2000a]. The GRINGO software, developed by the Institute of Engineering Surveying and Space Geodesy at Nottingham University [IESSG, 2002], captures the raw data from the receiver and converts it to Receiver INdependent EXchange (RINEX) format. The associated P4 software post-processes this data together with RINEX data from a reference site (typically one of the Ordnance Survey Active GPS Stations), to compute the coordinates of the Garmin receiver.

A basic model Garmin receiver (GPS12) was purchased, together with the GRINGO/P4 software (full carrier phase version). As illustrated below, the receiver was



Figure 2 – GPS Receiver

mounted on top of a total station, simply to facilitate centring over a reference mark and to raise the receiver above low-level obstructions to the line of sight. The mounting also incorporates a simple aluminium ground plane to minimise multipath reflections. Since the position of the electrical centre of the antenna inside the receiver is unknown, there is a maximum error of 7 cm in plan position and 3 cm in height, but these are small compared to the accuracy required and have been ignored.

The reference site used was Daresbury (station id DARE), which is the nearest active station of the OS National GPS Network (approximately 30 km distant from the Poulton site).

The Grid InQuest software [Ordnance Survey, 2000b], developed by Quest Geodetic Software Solutions for the Ordnance Survey, was used to convert the ETRS89 coordinates produced by GRINGO into their National Grid equivalents.

**4.2 Observations at OS Passive Station**

In order to validate the equipment and techniques used and to assess the absolute positioning accuracy which could be obtained, measurements were carried out on 09 August 2004 at Shotwicklodge, which is a National GPS Network passive station (station no. C1SJ3471). The data was then processed using various techniques and the calculated coordinates compared to the published coordinates of the station. Shotwicklodge was chosen because it and the Poulton site are similar distances from the Daresbury active station (approximately 25 km as compared to 30 km).

Note that the published coordinates of Daresbury active station have a quoted accuracy (2 or 95%) of 0.009 m in plan and 0.016 m in height, while the accuracy of the Shotwicklodge coordinates is quoted as 0.055 m in plan and 0.066 m in height.

**4.3 Effect of Different Ephemerides and Observables**

The full set of data (1 hour’s observations) was processed using all combinations of ephemeris (broadcast and precise-rapid) and observable (pseudorange and carrier phase). The results are shown in Table 1 below, expressed as differences between the calculated coordinates and the published coordinates of the station, in the National Grid reference system.

The choice of ephemeris has a negligible effect on the results, which is perhaps not surprising when using a differential (DGPS) solution. There is a clear difference between the pseudorange and carrier phase data, with the latter producing results which are an order of magnitude better than the former.

Ephem-eris	Observable	E (m)	N (m)	Plan (m)	Ht (m)
Broadcast	Pseudorange	+1.12	+0.56	1.25	+1.82
Broadcast	Carrier Phase	-0.11	-0.02	0.12	-0.07
Precise	Pseudorange	+1.12	+0.56	1.25	+1.81
Precise	Carrier Phase	-0.11	-0.02	0.12	-0.08

Table 1 – Differences in Absolute Position

#### 4.4 Effect of Varying Observation Period

Using the most accurate combination of data (precise-rapid ephemeris + carrier phase), the coordinates were calculated using various time periods extracted from the full data. In each case, the data was taken from the start of the overall observation period.

Observation Period (mins)	E (m)	N (m)	Plan (m)	Ht (m)
60	-0.11	-0.02	0.12	-0.08
30	+0.06	-0.09	0.11	-0.07
15	+0.05	-0.13	0.14	-0.11
5	+0.32	+0.11	0.34	-0.39

Table 2 – Effects of Different Observation Periods

There seems to be no significant degradation of accuracy with 15 minutes of observations and even 5 minutes of data produces coordinates which are well within 1m of the published values.

#### 4.5 GPS Observations at Poulton

In order to assess the relative positioning accuracy which could be obtained, GPS measurements were carried out on 28 August and 04 September 2004 at the Poulton site, using 3 stations of the site control network. As described in Section 2, this network had been observed and adjusted during 2003 to generate horizontal coordinates (referenced to the local grid) and heights (based on Ordnance datum from a nearby benchmark). The *a posteriori* standard errors of the inter-station distances were all under 1.5 cm, while those for the heights were all under 1 cm.

Each station was observed with the GPS receiver for 30 minutes and the results processed using both the broadcast (BE) and precise-rapid (PE) ephemerides.

Table 3 compares the lengths of the lines between the 3 stations as derived from ground survey (on the one hand) and GPS (on the other hand). For the purposes of comparison, the lengths determined from ground survey have been converted to corresponding lengths in the National

Grid projection using the local scale factor of 0.99965 (the MSL correction is negligible at this height AOD and for these lengths of lines).

Line	Length from Ground Survey	Length from GPS Survey (BE)	Length from GPS Survey (PE)	GPS (BE) - Ground	GPS (PE) - Ground
Ramp – Pad	141.55	141.36	141.45	-0.19	-0.10
Pad – TR1 TBM	209.77	209.90	209.93	+0.13	+0.16
TR1 TBM – Ramp	269.28	269.49	269.48	+0.21	+0.20
		<b>Average Absolute Value</b>		0.18	0.15

Table 3 – Comparison of Line Lengths (m)

Table 4 compares the orthometric heights of the 3 stations derived using the same techniques. These results show remarkably good agreement between the ground survey and GPS-derived values, particularly (and perhaps surprisingly!) in the heights.

Station	Height from Ground Survey	Height from GPS Survey (BE)	Height from GPS Survey (PE)	GPS (BE) - Ground	GPS (PE) - Ground
Ramp	17.16	17.13	17.13	-0.03	-0.03
Pad	15.00	14.88	15.07	-0.12	+0.07
TR1 TBM	15.77	15.73	15.76	-0.04	-0.01
		<b>Average Absolute Value</b>		0.06	0.04

Table 4 – Comparison of Station Heights (m)

#### 4.6 Recommendations for Future Observations

Observations should be taken for a minimum of 30 minutes and processed using carrier phase data, preferably with the precise ephemeris. This should result in an accuracy of around 20 cm in both plan and orthometric height, which is more than adequate for archaeological purposes. If the precise ephemeris is not available, then the broadcast ephemeris can be used with only a small reduction in accuracy.

## 5. Transformations between Trench I and National Grid Coordinate Systems

Three-parameter transformations (a rotation + 2 shifts) were calculated between the Poulton Trench I and National Grid coordinate systems, in both directions. These transformations also take account of the National Grid local scale factor (0.99965). The data used were the coordinates of the Ramp, Pad and TR1 TBM stations, which are known in both systems. The transformations were calculated as follows:

- The bearing of each line between the three stations was calculated in both systems and the average difference taken as the rotation between the two systems.
- The coordinates of each station in one system were rotated (using the value determined in the first step) and scaled using the local scale factor: the shifts were calculated as the average difference between these transformed coordinates and the corresponding coordinates in the other system.

The mean absolute difference between the coordinates in one system and the corresponding transformed coordinates from the other system is 6.5 cm.

### 5.1 From National Grid system (NG) to Poulton Trench I system (TRI)

$$E_{TRI} = (0.86545919 \times E_{NG}) + (0.50167794 \times N_{NG}) - 474254.16$$

$$N_{TRI} = (-0.50167794 \times E_{NG}) + (0.86545919 \times N_{NG}) - 139371.76$$

**Example:** TR1 TBM has coordinates in NG system of 340372.05E, 358364.24N. Coordinates in TRI system are as follows:

$$E_{TRI} = (0.86545919 \times 340372.05) + (0.50167794 \times 358364.24) - 474254.16 = 107.39$$

$$N_{TRI} = (-0.50167794 \times 340372.05) + (0.86545919 \times 358364.24) - 139371.76 = 20.72$$

### 5.2 From Poulton Trench I system (TRI) to National Grid system (NG)

$$E_{NG} = (0.86485348 \times E_{TRI}) - (0.50132682 \times N_{TRI}) + 340289.56$$

$$N_{NG} = (0.50132682 \times E_{TRI}) + (0.86485348 \times N_{TRI}) + 358292.49$$

**Example:** Ramp has coordinates in TRI system of 98.51E, 290.08N. Coordinates in NG system are as follows:

$$E_{NG} = (0.86485348 \times 98.51) - (0.50132682 \times 290.08) + 340289.56 = 340229.33$$

$$N_{NG} = (0.50132682 \times 98.51) + (0.86485348 \times 290.08) + 358292.49 = 358592.75$$

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## Appendices

### Appendix I. Adjustment Report – Trench I Control Point

\*\*\*\*\*  
REPORT OF LEAST SQUARE ADJUSTMENT  
\*\*\*\*\*

Data File: C:\Documents and Settings\Steve\My Documents\Network\Poulton TRI.obs  
Run Date: 22/07/2003 18:52:19

Software: EasyNet 2.4  
Copyright: Yuanda IT Services  
For Evaluation Purpose Only

=====  
LIST OF COORDINATES  
=====

#### Fixed Coordinates

-----  
Number: 7

Point	N (m)	E (m)
10015	15.0000	100.0000
10025	25.0000	100.0000
11025	25.0000	110.0000
12015	15.0000	120.0000
12025	25.0000	120.0000
13015	15.0000	130.0000
13025	25.0000	130.0000

#### Adjusted Coordinates

-----  
Number: 1

Point	N (m)	E (m)
TBM	20.8471	107.3681

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OBSERVATIONS AND ADJUSTMENTS

=====

Convergence Iterations: 2  
 Convergence Limit: 0.00010 1  
 Number of Observations: 14  
 Redundant Observations: 11  
 Error Factor: 1.54

Adjustment Passes the Chi Square Test at 0.05

D i s t a n c e s

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Number: 7 Error Factor: 1.61

-----

From	To	Observed (m)	StdErr (m)	Residual (m)	Adjusted (m)
TBM	12015	13.8690	0.0229	0.0505	13.9195
TBM	13015	23.3530	0.0229	0.0220	23.3750
TBM	13025	22.9730	0.0229	0.0368	23.0098
TBM	12025	13.3280	0.0229	-0.0310	13.2970
TBM	11025	4.9370	0.0229	-0.0204	4.9166
TBM	10025	8.4800	0.0229	-0.0221	8.4579
TBM	10015	9.3640	0.0229	0.0423	9.4063

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D i r e c t i o n s

-----

Number: 7 Error Factor: 1.45

-----

From	To	Observed (d-m-s)	StdErr (d-m-s)	Residual (d-m-s)	Adjusted (d-m-s)
TBM	11025	34-14-00.0	0-15-35.2	0-00-56.5	34-14-56.5
TBM	12025	73-48-30.0	0-05-47.6	-0-07-21.7	73-41-08.3
TBM	13025	81-33-55.0	0-03-20.9	-0-04-43.3	81-29-11.7
TBM	13015	106-17-55.0	0-03-18.0	0-04-19.0	106-22-14.0
TBM	12015	116-45-20.0	0-05-32.7	-0-01-56.3	116-43-23.7
TBM	10015	233-08-20.0	0-08-10.3	0-18-40.0	233-27-00.0
TBM	10025	301-15-35.0	0-09-02.1	0-01-54.0	301-17-29.0
					Orientation: 358-06-55.7

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Miscloses

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ADJUSTED VALUES & STANDARD DIVIATIONS OF BEARINGS & DISTANCES

=====

From	To	Bearing (d-m-s)	StdDev (d-m-s)	Distance (m)	StdDev (m)
10015	TBM	51-33-55.8	0-05-22.2	9.4063	0.0143
10025	TBM	119-24-24.8	0-06-09.1	8.4579	0.0138
11025	TBM	212-21-52.3	0-09-43.5	4.9166	0.0150
12015	TBM	294-50-19.4	0-03-46.4	13.9195	0.0136
12025	TBM	251-48-04.0	0-03-58.6	13.2970	0.0135
13015	TBM	284-29-09.7	0-02-16.9	23.3750	0.0134
13025	TBM	259-36-07.5	0-02-19.3	23.0098	0.0133

=====

STANDARD DEVIATIONS & ERROR ELLIPSES OF POINTS

=====

Point	StdDev of N (m)	StdDev of E (m)	Semi-Major Axis (m)	Semi-Minor Axis (m)	Bearing of Major Axis (d-m-s)
TBM	0.0156	0.0132	0.0156	0.0132	0-41-44.1

## Appendix 2. Adjustment Report – Ring Ditch Trench Control Point

\*\*\*\*\*  
REPORT OF LEAST SQUARE ADJUSTMENT  
\*\*\*\*\*

Job: Untitled  
Data File: C:\Documents and Settings\Steve\My Documents\Network\Poulton  
Ring.obs  
Run Date: 22/07/2003 18:58:52

Software: EasyNet 2.4  
Copyright: Yuanda IT Services  
For Evaluation Purpose Only

=====  
LIST OF COORDINATES  
=====

### Fixed Coordinates

-----  
Number: 6  
-----

Point	N (m)	E (m)
500400	400.0000	500.0000
500410	410.0000	500.0000
500420	420.0000	500.0000
506400	400.0000	506.5000
506410	410.0000	506.5000
506420	420.0000	506.5000

### Adjusted Coordinates

-----  
Number: 1  
-----

Point	N (m)	E (m)
TBM	418.2940	492.8387

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OBSERVATIONS AND ADJUSTMENTS

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Convergence Iterations: 3  
 Convergence Limit: 0.00010 1  
 Number of Observations: 11  
 Redundant Observations: 8  
 Error Factor: 0.72

Adjustment Passes the Chi Square Test at 0.05

D i s t a n c e s

-----

Number: 5 Error Factor: 0.57

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From	To	Observed (m)	StdErr (m)	Residual (m)	Adjusted (m)
TBM	500400	19.6370	0.0229	0.0088	19.6458
TBM	506400	22.8130	0.0229	0.0191	22.8321
TBM	500410	10.9620	0.0229	-0.0041	10.9579
TBM	506410	15.9900	0.0229	-0.0080	15.9820
TBM	506420	13.7590	0.0229	0.0084	13.7674

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D i r e c t i o n s

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Number: 6 Error Factor: 0.83

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From	To	Observed (d-m-s)	StdErr (d-m-s)	Residual (d-m-s)	Adjusted (d-m-s)
TBM	500420	94-03-20.0	0-10-21.5	0-02-00.4	94-05-20.4
TBM	506420	100-25-25.0	0-05-33.9	-0-03-12.3	100-22-12.7
TBM	506410	138-51-30.0	0-04-49.0	-0-06-26.9	138-45-03.1
TBM	500410	156-37-05.0	0-07-02.8	0-03-42.3	156-40-47.3
TBM	506400	160-41-45.0	0-03-22.7	0-02-28.6	160-44-13.6
TBM	500400	176-05-30.0	0-03-55.9	0-01-05.8	176-06-35.8
				Orientation:	342-30-42.5

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Miscloses

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ADJUSTED VALUES & STANDARD DIVIATIONS OF BEARINGS & DISTANCES

=====

From	To	Bearing (d-m-s)	StdDev (d-m-s)	Distance (m)	StdDev (m)
500400	TBM	338-37-18.3	0-02-30.6	19.6458	0.0089
500410	TBM	319-11-29.8	0-04-48.8	10.9579	0.0070
500420	TBM	256-36-02.9	0-04-40.2	7.3617	0.0136
506400	TBM	323-14-56.1	0-02-17.7	22.8321	0.0072
506410	TBM	301-15-45.6	0-03-14.1	15.9820	0.0076
506420	TBM	262-52-55.2	0-02-43.7	13.7674	0.0128

=====

STANDARD DEVIATIONS & ERROR ELLIPSES OF POINTS

=====

Point	StdDev of N (m)	StdDev of E (m)	Semi-Major Axis (m)	Semi-Minor Axis (m)	Bearing of Major Axis (d-m-s)
TBM	0.0119	0.0119	0.0154	0.0069	44-38-56.0

### Appendix 3. Adjustment Report – Horizontal Control Network

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Poulton Control Network  
-----

Number of Control Stations - 1  
Number of Unknown Stations - 13  
Number of Distance observations - 39  
Number of Angle observations - 31  
Number of Azimuth observations - 1

\*\*\*\*\*  
Initial approximations for unknown stations  
\*\*\*\*\*

Station	X	Y
Ramp	98.10	290.070
RingDitch	124.020	139.050
120E25N	120.020	25.000
BehindHdge	149.740	6.390
Geophys1	-117.000	11.790
Pad	-7.610	196.400
Geophys2	97.790	41.640
506E420N	137.810	139.270
Gatepost1	-121.000	207.500
Gatepost2	-121.770	203.850
Runway	80.650	324.910
PondPipe	-123.500	521.820
Geophys3	151.390	10.560

Control Stations

~~~~~

| Station | X       | Y      |
|---------|---------|--------|
| TR1TBM  | 107.368 | 20.847 |

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\*\*\*\*\*

Distance Observations

\*\*\*\*\*

| Station<br>Occupied | Station<br>Sighted | Distance | S     |
|---------------------|--------------------|----------|-------|
| Pad                 | Ramp               | 141.600  | 0.017 |
| Pad                 | 506E420N           | 156.240  | 0.017 |
| Pad                 | RingDitch          | 143.600  | 0.017 |
| Pad                 | 120E25N            | 213.710  | 0.017 |
| Pad                 | Geophys2           | 187.290  | 0.017 |
| Pad                 | TR1TBM             | 209.840  | 0.017 |
| Pad                 | Geophys1           | 214.560  | 0.017 |
| Pad                 | Gatepost2          | 114.370  | 0.017 |
| Pad                 | PondPipe           | 345.440  | 0.017 |
| TR1TBM              | Geophys1           | 224.550  | 0.017 |
| TR1TBM              | Gatepost2          | 293.170  | 0.017 |
| TR1TBM              | Pad                | 209.850  | 0.017 |
| TR1TBM              | Geophys2           | 22.890   | 0.017 |
| TR1TBM              | Ramp               | 269.370  | 0.017 |
| TR1TBM              | RingDitch          | 119.370  | 0.017 |
| TR1TBM              | 120E25N            | 13.320   | 0.017 |
| TR1TBM              | BehindHdge         | 44.770   | 0.017 |
| Ramp                | 506E420N           | 155.840  | 0.017 |
| Ramp                | RingDitch          | 153.150  | 0.017 |
| Ramp                | TR1TBM             | 269.400  | 0.017 |
| Ramp                | Geophys2           | 248.490  | 0.017 |
| Ramp                | Geophys1           | 351.980  | 0.017 |
| Ramp                | Pad                | 141.610  | 0.017 |
| Ramp                | Gatepost2          | 236.550  | 0.017 |
| Ramp                | Runway             | 39.150   | 0.017 |
| Runway              | Ramp               | 39.110   | 0.017 |
| Runway              | PondPipe           | 283.720  | 0.017 |
| RingDitch           | 120E25N            | 114.160  | 0.017 |
| RingDitch           | TR1TBM             | 119.370  | 0.017 |
| RingDitch           | Geophys2           | 100.920  | 0.017 |
| RingDitch           | Gatepost1          | 254.460  | 0.017 |
| RingDitch           | Pad                | 143.600  | 0.017 |
| RingDitch           | PondPipe           | 455.860  | 0.017 |
| RingDitch           | Ramp               | 153.170  | 0.017 |
| BehindHdge          | TR1TBM             | 44.780   | 0.017 |
| BehindHdge          | 120E25N            | 35.050   | 0.017 |
| BehindHdge          | Geophys3           | 4.480    | 0.017 |
| Pad                 | Gatepost1          | 114.000  | 0.017 |
| Gatepost1           | Gatepost2          | 3.720    | 0.017 |

\*\*\*\*\*

## Angle Observations

\*\*\*\*\*

| Station<br>Backsighted | Station<br>Occupied | Station<br>Foresighted | Angle        | S    |
|------------------------|---------------------|------------------------|--------------|------|
| Ramp                   | Pad                 | 506E420N               | 62° 52' 17"  | 31"  |
| 506E420N               | Pad                 | RingDitch              | 2° 04' 43"   | 30"  |
| RingDitch              | Pad                 | 120E25N                | 29° 47' 25"  | 27"  |
| 120E25N                | Pad                 | Geophys2               | 2° 25' 20"   | 23"  |
| Geophys2               | Pad                 | TR1TBM                 | 1° 01' 57"   | 23"  |
| TR1TBM                 | Pad                 | Geophys1               | 63° 52' 50"  | 22"  |
| Geophys1               | Pad                 | Gatepost2              | 63° 06' 45"  | 32"  |
| Gatepost2              | Pad                 | PondPipe               | 66° 37' 40"  | 30"  |
| Geophys1               | TR1TBM              | Gatepost2              | 40° 55' 45"  | 19"  |
| Gatepost2              | TR1TBM              | Pad                    | 18° 09' 33"  | 20"  |
| Pad                    | TR1TBM              | Geophys2               | 8° 28' 52"   | 138" |
| Geophys2               | TR1TBM              | Ramp                   | 22° 51' 28"  | 137" |
| Ramp                   | TR1TBM              | RingDitch              | 9° 54' 07"   | 29"  |
| RingDitch              | TR1TBM              | 120E25N                | 63° 49' 38"  | 237" |
| 120E25N                | TR1TBM              | BehindHdge             | 36° 59' 30"  | 244" |
| 506E420N               | Ramp                | RingDitch              | 5° 00' 58"   | 29"  |
| RingDitch              | Ramp                | TR1TBM                 | 7° 42' 20"   | 24"  |
| TR1TBM                 | Ramp                | Geophys2               | 2° 02' 02"   | 18"  |
| Geophys2               | Ramp                | Geophys1               | 37° 36' 10"  | 17"  |
| Geophys1               | Ramp                | Pad                    | 10° 48' 28"  | 25"  |
| Pad                    | Ramp                | Gatepost2              | 20° 03' 47"  | 27"  |
| Gatepost2              | Ramp                | Runway                 | 84° 13' 48"  | 82"  |
| Ramp                   | Runway              | PondPipe               | 161° 06' 05" | 82"  |
| 120E25N                | RingDitch           | TR1TBM                 | 6° 00' 35"   | 38"  |
| TR1TBM                 | RingDitch           | Geophys2               | 7° 01' 57"   | 41"  |
| Geophys2               | RingDitch           | Gatepost1              | 90° 33' 43"  | 34"  |
| Gatepost1              | RingDitch           | Pad                    | 7° 54' 45"   | 26"  |
| Pad                    | RingDitch           | PondPipe               | 33° 34' 22"  | 24"  |
| PondPipe               | RingDitch           | Ramp                   | 23° 19' 05"  | 23"  |
| TR1TBM                 | BehindHdge          | 120E25N                | 13° 12' 08"  | 112" |
| 120E25N                | BehindHdge          | Geophys3               | 79° 32' 37"  | 705" |

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Azimuth Observations

\*\*\*\*\*

| Station<br>Occupied | Station<br>Sighted | Azimuth    | S  |
|---------------------|--------------------|------------|----|
| TR1TBM              | Ramp               | 358°06'55" | 0" |

\*\*\*\*\*

Adjusted stations

\*\*\*\*\*

| Station    | X        | Y       | Error ellipse confidence level at 0.950 |        |        |        | t       |
|------------|----------|---------|-----------------------------------------|--------|--------|--------|---------|
|            |          |         | Sx                                      | Sy     | Su     | Sv     |         |
| Ramp       | 98.508   | 290.081 | 0.0003                                  | 0.0078 | 0.0199 | 0.0000 | 178.12° |
| RingDitch  | 124.021  | 139.061 | 0.0076                                  | 0.0075 | 0.0195 | 0.0189 | 56.26°  |
| 120E25N    | 120.032  | 24.989  | 0.0098                                  | 0.0103 | 0.0260 | 0.0247 | 169.64° |
| BehindHdge | 149.738  | 6.377   | 0.0216                                  | 0.0502 | 0.1358 | 0.0260 | 21.12°  |
| Geophys1   | -117.002 | 11.781  | 0.0113                                  | 0.0138 | 0.0362 | 0.0272 | 157.15° |
| Pad        | -7.639   | 196.366 | 0.0071                                  | 0.0084 | 0.0223 | 0.0167 | 27.87°  |
| Geophys2   | 97.817   | 41.599  | 0.0073                                  | 0.0092 | 0.0236 | 0.0180 | 164.57° |
| 506E420N   | 137.796  | 139.269 | 0.0149                                  | 0.0139 | 0.0389 | 0.0339 | 60.50°  |
| Gatepost1  | -121.077 | 207.507 | 0.0139                                  | 0.0182 | 0.0468 | 0.0343 | 13.62°  |
| Gatepost2  | -121.745 | 203.837 | 0.0110                                  | 0.0131 | 0.0335 | 0.0274 | 15.66°  |
| Runway     | 80.649   | 324.895 | 0.0106                                  | 0.0129 | 0.0326 | 0.0268 | 176.59° |
| PondPipe   | -123.652 | 521.759 | 0.0260                                  | 0.0193 | 0.0761 | 0.0304 | 56.76°  |
| Geophys3   | 151.388  | 10.542  | 0.0227                                  | 0.0551 | 0.1435 | 0.0465 | 14.47°  |

\*\*\*\*\*

## Adjusted Distance Observations

\*\*\*\*\*

| Station<br>Occupied | Station<br>Sighted | Distance | V       | S      | Std.Res. | Red.#  |
|---------------------|--------------------|----------|---------|--------|----------|--------|
| Pad                 | Ramp               | 141.598  | -0.0022 | 0.0080 | -0.148   | 0.776  |
| Pad                 | 506E420N           | 156.242  | 0.0015  | 0.0133 | 0.146    | 0.385  |
| Pad                 | RingDitch          | 143.591  | -0.0092 | 0.0074 | -0.598   | 0.810  |
| Pad                 | 120E25N            | 213.706  | -0.0043 | 0.0105 | -0.319   | 0.616  |
| Pad                 | Geophys2           | 187.280  | -0.0096 | 0.0092 | -0.669   | 0.709  |
| Pad                 | TR1TBM             | 209.842  | 0.0017  | 0.0072 | 0.112    | 0.822  |
| Pad                 | Geophys1           | 214.550  | -0.0096 | 0.0110 | -0.744   | 0.579  |
| Pad                 | Gatepost2          | 114.350  | -0.0201 | 0.0108 | -1.532   | 0.595  |
| Pad                 | PondPipe           | 345.455  | 0.0154  | 0.0121 | 1.294    | 0.492  |
| TR1TBM              | Geophys1           | 224.553  | 0.0031  | 0.0112 | 0.242    | 0.564  |
| TR1TBM              | Gatepost2          | 293.221  | 0.0506  | 0.0112 | 3.962    | 0.563* |
| TR1TBM              | Pad                | 209.842  | -0.0083 | 0.0072 | -0.537   | 0.822  |
| TR1TBM              | Geophys2           | 22.844   | -0.0459 | 0.0093 | -3.224   | 0.702  |
| TR1TBM              | Ramp               | 269.380  | 0.0097  | 0.0078 | 0.645    | 0.787  |
| TR1TBM              | RingDitch          | 119.381  | 0.0108  | 0.0076 | 0.707    | 0.802  |
| TR1TBM              | 120E25N            | 13.324   | 0.0042  | 0.0098 | 0.304    | 0.669  |
| TR1TBM              | BehindHdge         | 44.773   | 0.0031  | 0.0105 | 0.233    | 0.620  |
| Ramp                | 506E420N           | 155.845  | 0.0048  | 0.0121 | 0.404    | 0.497  |
| Ramp                | RingDitch          | 153.160  | 0.0102  | 0.0076 | 0.673    | 0.798  |
| Ramp                | TR1TBM             | 269.380  | -0.0203 | 0.0078 | -1.344   | 0.787  |
| Ramp                | Geophys2           | 248.483  | -0.0068 | 0.0096 | -0.487   | 0.681  |
| Ramp                | Geophys1           | 351.989  | 0.0085  | 0.0111 | 0.661    | 0.574  |
| Ramp                | Pad                | 141.598  | -0.0122 | 0.0080 | -0.815   | 0.776  |
| Ramp                | Gatepost2          | 236.537  | -0.0134 | 0.0113 | -1.061   | 0.555  |
| Ramp                | Runway             | 39.128   | -0.0225 | 0.0108 | -1.714   | 0.594  |
| Runway              | Ramp               | 39.128   | 0.0175  | 0.0108 | 1.339    | 0.594  |
| Runway              | PondPipe           | 283.715  | -0.0050 | 0.0131 | -0.458   | 0.410  |
| RingDitch           | 120E25N            | 114.142  | -0.0184 | 0.0103 | -1.361   | 0.633  |
| RingDitch           | TR1TBM             | 119.381  | 0.0108  | 0.0076 | 0.707    | 0.802  |
| RingDitch           | Geophys2           | 100.923  | 0.0029  | 0.0094 | 0.202    | 0.695  |
| RingDitch           | Gatepost1          | 254.476  | 0.0156  | 0.0127 | 1.379    | 0.443  |
| RingDitch           | Pad                | 143.591  | -0.0092 | 0.0074 | -0.598   | 0.810  |
| RingDitch           | PondPipe           | 455.850  | -0.0095 | 0.0113 | -0.752   | 0.555  |
| RingDitch           | Ramp               | 153.160  | -0.0098 | 0.0076 | -0.644   | 0.798  |
| BehindHdge          | TR1TBM             | 44.773   | -0.0069 | 0.0105 | -0.514   | 0.620  |
| BehindHdge          | 120E25N            | 35.055   | 0.0050  | 0.0124 | 0.434    | 0.465  |
| BehindHdge          | Geophys3           | 4.480    | -0.0000 | 0.0170 | 0.000    | 0.000  |
| Pad                 | Gatepost1          | 113.983  | -0.0167 | 0.0127 | -1.476   | 0.446  |
| Gatepost1           | Gatepost2          | 3.730    | 0.0097  | 0.0146 | 1.110    | 0.265  |

The Poulton Survey Control Network

\*\*\*\*\*

Adjusted Angle Observations

\*\*\*\*\*

| Station<br>Backsighted | Station<br>Occupied | Station<br>Foresighted | Angle      | V       | S     | Std.Res. | Red.# |
|------------------------|---------------------|------------------------|------------|---------|-------|----------|-------|
| Ramp                   | Pad                 | 506E420N               | 62°52'29"  | 12.5"   | 17.8  | 0.5      | 0.658 |
| 506E420N               | Pad                 | RingDitch              | 2°05'12"   | 29.0"   | 17.9  | 1.2      | 0.645 |
| RingDitch              | Pad                 | 120E25N                | 29°47'37"  | 12.4"   | 12.2  | 0.5      | 0.796 |
| 120E25N                | Pad                 | Geophys2               | 2°24'54"   | -25.9"  | 11.2  | -1.3     | 0.764 |
| Geophys2               | Pad                 | TR1TBM                 | 1°02'08"   | 11.2"   | 8.1   | 0.5      | 0.879 |
| TR1TBM                 | Pad                 | Geophys1               | 63°52'49"  | -0.9"   | 12.2  | -0.0     | 0.691 |
| Geophys1               | Pad                 | Gatepost2              | 63°06'02"  | -42.6"  | 18.8  | -1.7     | 0.649 |
| Gatepost2              | Pad                 | PondPipe               | 66°37'51"  | 11.2"   | 20.8  | 0.5      | 0.519 |
| Geophys1               | TR1TBM              | Gatepost2              | 40°55'41"  | -4.1"   | 11.1  | -0.3     | 0.651 |
| Gatepost2              | TR1TBM              | Pad                    | 18°09'05"  | -27.9"  | 7.9   | -1.6     | 0.834 |
| Pad                    | TR1TBM              | Geophys2               | 8°31'16"   | 144.1"  | 64.6  | 1.2      | 0.779 |
| Geophys2               | TR1TBM              | Ramp                   | 22°49'43"  | -104.7" | 64.9  | -0.9     | 0.777 |
| Ramp                   | TR1TBM              | RingDitch              | 9°54'12"   | 4.8"    | 13.1  | 0.2      | 0.799 |
| RingDitch              | TR1TBM              | 120E25N                | 63°52'18"  | 159.8"  | 158.3 | 0.9      | 0.553 |
| 120E25N                | TR1TBM              | BehindHdge             | 36°57'56"  | -94.3"  | 189.0 | -0.6     | 0.402 |
| 506E420N               | Ramp                | RingDitch              | 5°00'46"   | -12.1"  | 18.7  | -0.5     | 0.588 |
| RingDitch              | Ramp                | TR1TBM                 | 7°42'14"   | -5.9"   | 10.3  | -0.3     | 0.821 |
| TR1TBM                 | Ramp                | Geophys2               | 2°02'39"   | 36.7"   | 6.1   | 2.1      | 0.892 |
| Geophys2               | Ramp                | Geophys1               | 37°35'39"  | -31.1"  | 8.8   | -2.2     | 0.730 |
| Geophys1               | Ramp                | Pad                    | 10°48'22"  | -6.2"   | 10.9  | -0.3     | 0.805 |
| Pad                    | Ramp                | Gatepost2              | 20°03'25"  | -22.2"  | 10.8  | -0.9     | 0.833 |
| Gatepost2              | Ramp                | Runway                 | 84°13'32"  | -15.6"  | 55.0  | -0.3     | 0.550 |
| Ramp                   | Runway              | PondPipe               | 161°05'45" | -19.9"  | 61.1  | -0.4     | 0.438 |
| 120E25N                | RingDitch           | TR1TBM                 | 6°00'57"   | 22.4"   | 17.6  | 0.7      | 0.787 |
| TR1TBM                 | RingDitch           | Geophys2               | 7°01'48"   | -8.7"   | 15.4  | -0.2     | 0.858 |
| Geophys2               | RingDitch           | Gatepost1              | 90°33'16"  | -27.4"  | 21.9  | -1.0     | 0.590 |
| Gatepost1              | RingDitch           | Pad                    | 7°55'05"   | 20.2"   | 13.8  | 0.9      | 0.712 |
| Pad                    | RingDitch           | PondPipe               | 33°34'08"  | -13.7"  | 14.5  | -0.7     | 0.630 |
| PondPipe               | RingDitch           | Ramp                   | 23°19'17"  | 11.7"   | 14.4  | 0.7      | 0.594 |
| TR1TBM                 | BehindHdge          | 120E25N                | 13°12'45"  | 37.1"   | 64.8  | 0.4      | 0.668 |
| 120E25N                | BehindHdge          | Geophys3               | 79°32'37"  | -0.0"   | 704.7 | 0.0      | 0.000 |

\*\*\*\*\*

Adjusted Azimuth Observations

\*\*\*\*\*

| Station<br>Occupied | Station<br>Sighted | Azimuth    | V    | S"   | Std.Res. | Red.# |
|---------------------|--------------------|------------|------|------|----------|-------|
| TR1TBM              | Ramp               | 358°06'55" | 0.0" | 0.0" | 0        | 0.000 |

\*\*\*\*\*

Adjustment Statistics

\*\*\*\*\*

Iterations = 3  
Redundancies = 45

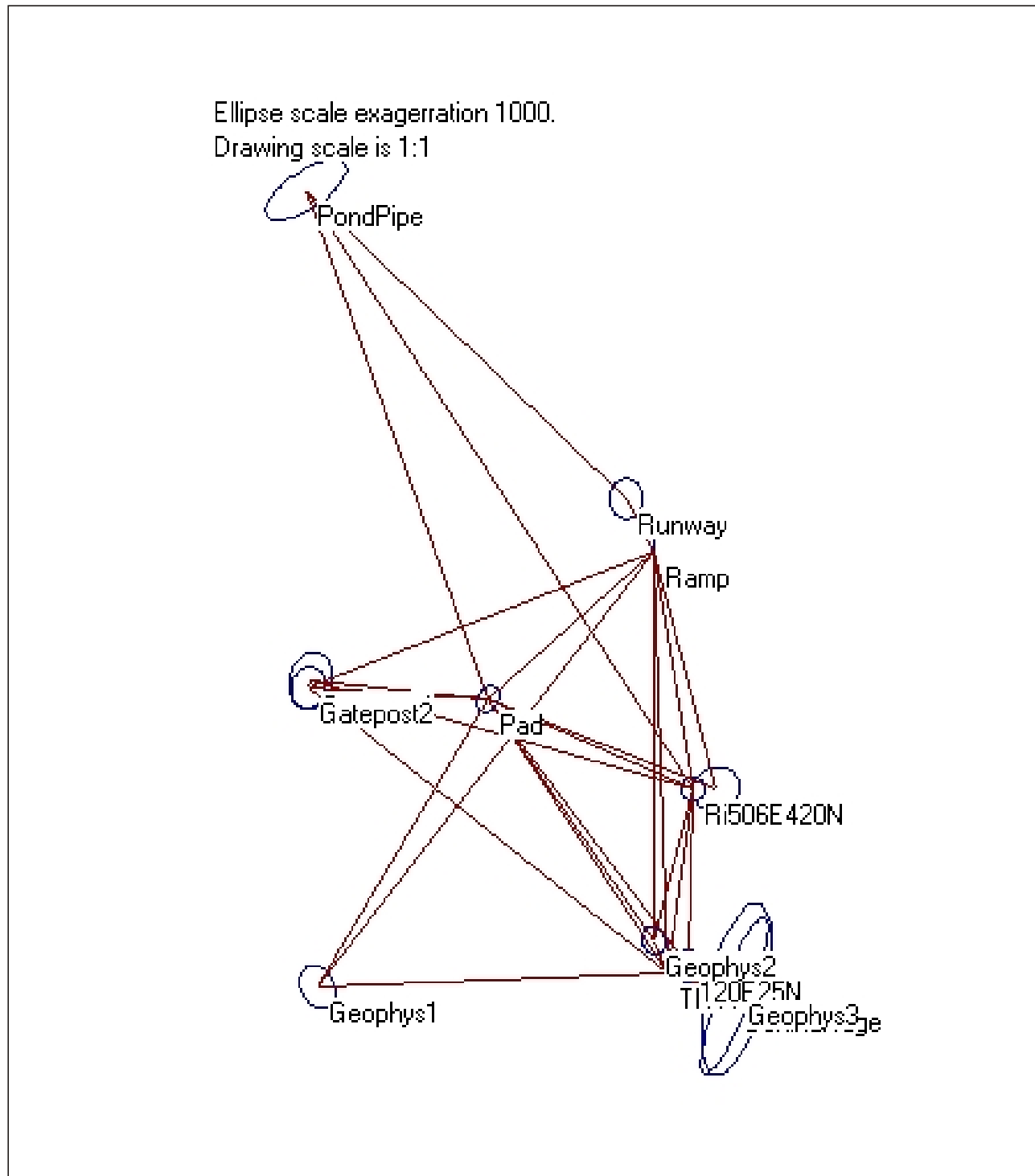
Reference Variance = 1.148  
Reference So = ±1.1

Passed  $\chi^2$  test at 95.0% significance level!  
 $\chi^2$  lower value = 28.37  
 $\chi^2$  upper value = 65.41

A priori value of 1 used for reference variance  
in computations of statistics.

Possible blunder in observations with Std.Res. > 4  
Convergence!

### Appendix 4. Network Diagram and Error Ellipses



## Appendix 5. Adjustment Report – Vertical Control Network

\*\*\*\*\*  
 \*\*\*\*\* Least Squares Adjustment of Differential Leveling \*\*\*\*\*  
 \*\*\*\*\*

-----  
 Poulton Vertical Network  
 -----

\*\*\*\*\*  
 Benchmark stations  
 \*\*\*\*\*

| Station | Elevation |
|---------|-----------|
| Tr1TBM  | 15.77     |

\*\*\*\*\*  
 Observed Elevation Differences  
 \*\*\*\*\*

| From      | To         | Elevation Difference | S        |
|-----------|------------|----------------------|----------|
| Pad       | Ramp       | 2.16                 | 141.6000 |
| Pad       | 506E420N   | 1.34                 | 156.2400 |
| Pad       | RingDitch  | 1.18                 | 143.6000 |
| Pad       | 120E25N    | 0.91                 | 213.7100 |
| Pad       | Geophys2   | 2.35                 | 187.2900 |
| Pad       | TR1TBM     | 0.77                 | 209.8400 |
| Pad       | Geophys1   | -1.87                | 214.5600 |
| Pad       | Gatepost2  | 0.99                 | 114.3700 |
| Pad       | PondPipe   | -0.52                | 345.4400 |
| TR1TBM    | Geophys1   | -2.64                | 224.5500 |
| TR1TBM    | Gatepost2  | 0.20                 | 293.1700 |
| TR1TBM    | Pad        | -0.77                | 209.8500 |
| TR1TBM    | Geophys2   | 1.59                 | 22.8900  |
| TR1TBM    | Ramp       | 1.39                 | 269.3700 |
| TR1TBM    | RingDitch  | 0.40                 | 119.3700 |
| TR1TBM    | 120E25N    | 0.16                 | 13.3200  |
| TR1TBM    | BehindHdge | -2.21                | 44.7700  |
| Ramp      | 506E420N   | -0.82                | 155.8400 |
| Ramp      | RingDitch  | -0.98                | 153.1500 |
| Ramp      | TR1TBM     | -1.39                | 269.4000 |
| Ramp      | Geophys2   | 0.18                 | 248.4900 |
| Ramp      | Geophys1   | -4.06                | 351.9800 |
| Ramp      | Pad        | -2.15                | 141.6100 |
| Ramp      | Gatepost2  | -1.18                | 236.5500 |
| Ramp      | Runway     | -1.55                | 39.1500  |
| Runway    | Ramp       | 1.55                 | 39.1100  |
| Runway    | PondPipe   | -1.12                | 283.7200 |
| RingDitch | 120E25N    | -0.25                | 114.1600 |
| RingDitch | TR1TBM     | -0.40                | 119.3700 |
| RingDitch | Geophys2   | 1.17                 | 100.9200 |

|            |           |       |          |
|------------|-----------|-------|----------|
| RingDitch  | Gatepost1 | -0.18 | 254.4600 |
| RingDitch  | Pad       | -1.18 | 143.6000 |
| RingDitch  | PondPipe  | -1.72 | 455.8600 |
| RingDitch  | Ramp      | 0.99  | 153.1700 |
| BehindHdge | TR1TBM    | 2.22  | 44.7800  |
| BehindHdge | Geophys3  | 1.14  | 4.4800   |
| Pad        | Gatepost2 | 1.00  | 114.3600 |
| Pad        | Gatepost1 | 1.01  | 114.0000 |
| Pad        | PondPipe  | -0.50 | 345.4600 |
| Pad        | Ramp      | 2.18  | 141.6100 |

Possible blunders with observations having Std.Res. > 0.00

Reference Variance = 0.0000006148

Reference So = ±0.00078

Failed to pass  $\chi^2$  test at 95.0% significance level!  
 $\chi^2$  lower value = 14.57  
 $\chi^2$  upper value = 43.19

\*\*\*\*\*

Adjusted Elevation Differences

\*\*\*\*\*

| From   | To         | Elevation Difference | V      | S     | Std.Res. | Red.# |
|--------|------------|----------------------|--------|-------|----------|-------|
| Pad    | Ramp       | 2.16                 | 0.005  | 0.004 | 0.00     | 0.85  |
| Pad    | 506E420N   | 1.34                 | 0.002  | 0.007 | 0.00     | 0.47  |
| Pad    | RingDitch  | 1.18                 | -0.000 | 0.004 | -0.00    | 0.83  |
| Pad    | 120E25N    | 0.93                 | 0.019  | 0.004 | 0.00     | 0.86  |
| Pad    | Geophys2   | 2.36                 | 0.007  | 0.004 | 0.00     | 0.83  |
| Pad    | TR1TBM     | 0.77                 | 0.000  | 0.004 | 0.00     | 0.89  |
| Pad    | Geophys1   | -1.88                | -0.006 | 0.007 | -0.00    | 0.58  |
| Pad    | Gatepost2  | 0.99                 | -0.000 | 0.005 | -0.00    | 0.64  |
| Pad    | PondPipe   | -0.51                | 0.006  | 0.008 | 0.00     | 0.73  |
| TR1TBM | Geophys1   | -2.65                | -0.006 | 0.008 | -0.00    | 0.59  |
| TR1TBM | Gatepost2  | 0.22                 | 0.020  | 0.006 | 0.00     | 0.81  |
| TR1TBM | Pad        | -0.77                | -0.000 | 0.004 | -0.00    | 0.89  |
| TR1TBM | Geophys2   | 1.59                 | -0.003 | 0.003 | -0.00    | 0.24  |
| TR1TBM | Ramp       | 1.39                 | 0.005  | 0.004 | 0.00     | 0.89  |
| TR1TBM | RingDitch  | 0.41                 | 0.010  | 0.004 | 0.00     | 0.82  |
| TR1TBM | 120E25N    | 0.16                 | -0.001 | 0.003 | -0.00    | 0.12  |
| TR1TBM | BehindHdge | -2.21                | -0.005 | 0.004 | -0.00    | 0.50  |
| Ramp   | 506E420N   | -0.82                | -0.002 | 0.007 | -0.00    | 0.46  |
| Ramp   | RingDitch  | -0.99                | -0.005 | 0.004 | -0.00    | 0.82  |
| Ramp   | TR1TBM     | -1.39                | -0.005 | 0.004 | -0.00    | 0.89  |
| Ramp   | Geophys2   | 0.19                 | 0.012  | 0.005 | 0.00     | 0.85  |
| Ramp   | Geophys1   | -4.04                | 0.019  | 0.008 | 0.00     | 0.73  |
| Ramp   | Pad        | -2.16                | -0.015 | 0.004 | -0.00    | 0.85  |
| Ramp   | Gatepost2  | -1.18                | 0.005  | 0.006 | 0.00     | 0.77  |
| Ramp   | Runway     | -1.55                | -0.001 | 0.003 | -0.00    | 0.52  |
| Runway | Ramp       | 1.55                 | 0.001  | 0.003 | 0.00     | 0.52  |
| Runway | PondPipe   | -1.13                | -0.009 | 0.008 | -0.00    | 0.63  |

|            |               |       |        |       |       |      |
|------------|---------------|-------|--------|-------|-------|------|
| RingDitch  | 120E25N       | -0.25 | -0.001 | 0.004 | -0.00 | 0.76 |
| RingDitch  | TR1TBM        | -0.41 | -0.010 | 0.004 | -0.00 | 0.82 |
| RingDitch  | Geophys2      | 1.18  | 0.007  | 0.004 | 0.00  | 0.72 |
| RingDitch  | Gatepost1     | -0.17 | 0.007  | 0.007 | 0.00  | 0.65 |
| RingDitch  | Pad           | -1.18 | 0.000  | 0.004 | 0.00  | 0.83 |
| RingDitch  | PondPipe      | -1.69 | 0.026  | 0.008 | 0.00  | 0.78 |
| RingDitch  | Ramp          | 0.99  | -0.005 | 0.004 | -0.00 | 0.82 |
| BehindHdge | TR1TBM        | 2.21  | -0.005 | 0.004 | -0.00 | 0.50 |
| BehindHdge | Geophys3      | 1.14  | -0.000 | 0.002 | -0.00 | 0.00 |
|            | Pad Gatepost2 | 0.99  | -0.010 | 0.005 | -0.00 | 0.64 |
|            | Pad Gatepost1 | 1.01  | -0.003 | 0.007 | -0.00 | 0.29 |
|            | Pad PondPipe  | -0.51 | -0.014 | 0.008 | -0.00 | 0.73 |
|            | Pad Ramp      | 2.16  | -0.015 | 0.004 | -0.00 | 0.85 |

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Adjusted Elevations

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| Station    | Elevation | S     |
|------------|-----------|-------|
| Tr1TBM     | 15.77     |       |
| Pad        | 15.00     | 0.004 |
| Ramp       | 17.16     | 0.004 |
| 506E420N   | 16.34     | 0.008 |
| RingDitch  | 16.18     | 0.004 |
| 120E25N    | 15.93     | 0.003 |
| Geophys2   | 17.36     | 0.003 |
| Geophys1   | 13.12     | 0.008 |
| Gatepost2  | 15.99     | 0.006 |
| PondPipe   | 14.49     | 0.008 |
| BehindHdge | 13.56     | 0.004 |
| Runway     | 15.61     | 0.005 |
| Gatepost1  | 16.01     | 0.008 |
| Geophys3   | 14.70     | 0.004 |

**Appendix 6. Control Station Coordinates**

The table below gives the coordinates of the Poulton control stations:

| Station      | Easting (m) | Northing (m) | Height (m) |
|--------------|-------------|--------------|------------|
| 120E 25N     | 120.03      | 24.99        | 15.93      |
| 506.5E 420N  | 137.80      | 139.27       | 16.34      |
| Behind Hedge | 149.74      | 6.38         | 13.56      |
| Gatepost 1   | -121.08     | 207.51       | 16.01      |
| Gatepost 2   | -121.75     | 203.84       | 15.99      |
| Geophys 1    | -117.00     | 11.78        | 13.12      |
| Geophys 2    | 97.82       | 41.60        | 17.36      |
| Geophys 3    | 151.39      | 10.54        | 14.70      |
| Pad          | -7.64       | 196.37       | 15.00      |
| Pond Pipe    | -123.65     | 521.76       | 14.49      |
| Ramp         | 98.51       | 290.08       | 17.16      |
| Ring Ditch   | 124.02      | 139.06       | 16.18      |
| Runway       | 80.65       | 324.90       | 15.61      |
| TR1 TBM      | 107.37      | 20.85        | 15.77      |

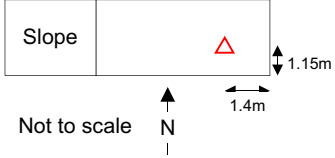
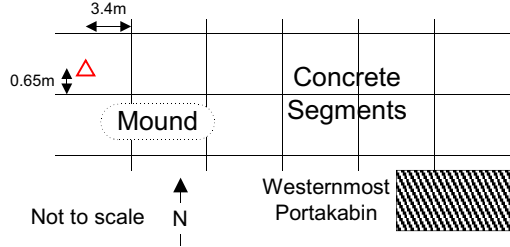
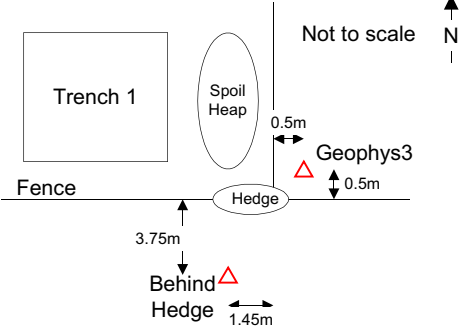
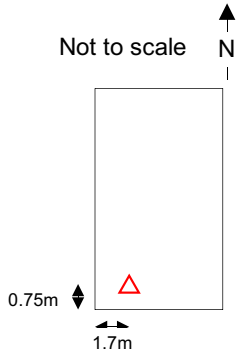
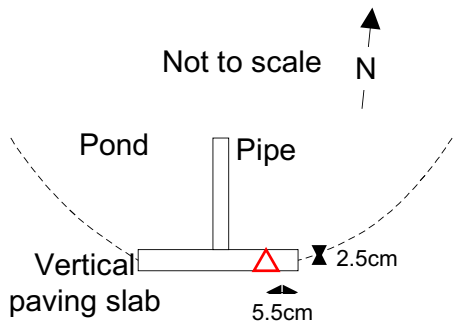
Descriptions of these stations are provided in Appendix 7.

These coordinates are all in the Trench I coordinate system.

Details of how to convert between this system and the Ring Ditch coordinate system are given in section 3.

Details of how to convert between this system and the National Grid coordinate system are given in section 5.

## Appendix 7. Control Station Descriptions

|                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Ramp</b><br/>Screw head on top of large concrete ramp immediately south of Portakabins:</p>                                                                                                                                                 | <p><b>Runway</b><br/>Screw head in runway to WNW of Portakabins:</p>                                     |
| <p><b>Ring Ditch</b><br/>Nail in peg at W side of Ring Ditch trench. 492.84E 418.29N in Ring Ditch grid.</p>                                                                                                                                                                                                                       | <p><b>506.5E 420N</b><br/>Top of grid pin in Ring Ditch trench.</p>                                                                                                                        |
| <p><b>TRI TBM</b><br/>TBM in Trench I – highest point on stone, marked with paint. 107.37E 20.85N in Trench I grid.</p>                                                                                                                                                                                                            | <p><b>I20E 25N</b><br/>Top of grid pin in Trench I.</p>                                                                                                                                    |
| <p><b>Geophys 1</b><br/>Top of Geophysics baseline 1 yellow marker, in SW corner of field.</p>                                                                                                                                                                                                                                     | <p><b>Geophys 2</b><br/>Centre of top of fence post at NW corner of Trench I (Geophysics baseline 2 yellow marker is resting against this post).</p>                                       |
| <p><b>Behind Hedge &amp; Geophys 3</b></p>  <p><b>Behind Hedge:</b><br/>Nail in peg at top of slope leading down to Pulford Brook.</p> <p><b>Geophys 3</b><br/>Top of Geophysics baseline 3 yellow marker, behind fence to E of spoil heap.</p> |                                                                                                                                                                                            |
| <p><b>Gatepost 1</b><br/>Centre of top of northernmost of pair of gateposts in W boundary hedge of field.</p>                                                                                                                                                                                                                      | <p><b>Gatepost 2</b><br/>Centre of top of southernmost of pair of gateposts in W boundary hedge of field.</p>                                                                              |
| <p><b>Pad</b><br/>Screw head on concrete pad in middle of field:</p>                                                                                                                                                                            | <p><b>Pond Pipe</b><br/>Mark on horizontal surface of paving slab set vertically on edge of pond:</p>  |

