

COMMUNICATIONS OF THE
DUBLIN INSTITUTE FOR ADVANCED STUDIES
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THE SIX INCH AND ONE INCH SHEET MAPS OF IRELAND
and
Methods for deducing Rectangular and Geographical
Coordinates for points thereon

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THOMAS MURPHY

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Summary

The coordinate systems employed in the production of the sheet maps of Ireland are described briefly. The transformation of coordinates from one to the other has been deduced from a study of historical documents.

Introduction

A point in Ireland is usually specified by one or more of five different coordinate systems namely:-

County Grid Coordinates (feet).

National Grid Coordinates (metres).

Latitude and Longitude on AIRY spheroid.

Latitude and Longitude on INTERNATIONAL spheroid.

European Datum 1950.

Universal Transverse Mercator Coordinates, Zone 29.

For geophysical studies in Ireland positional data are usually obtained from the large scale maps of the Ordnance Survey, and given in National Grid Coordinates and/or Latitude and Longitude on the AIRY ellipsoid.

The series which covers the complete country and the one still in use is at the scale of 1: 10 560, the so-called Six Inch series.

In particular, for gravity studies the accurate knowledge of the altitude and latitude at the point of measurement is essential. The former can be obtained satisfactorily from the Six Inch series but not the latter since no coordinate systems, geographical or otherwise, are marked thereon. This serious drawback only became apparent when widespread gravity measurements

were undertaken for the first time in Ireland in 1950.

To obtain the necessary information the positions of the gravity measurements were transferred to a set of smaller scale maps, the 1: 63 360 known as 'One Inch to a Mile' series. The Geographical Coordinates were then read off on the margin scales using a straight edge. This was sufficiently accurate at the time, but discrepancies became commonplace, particularly in the reading of longitude, which on the sheet is given west of Greenwich. To reduce the frequency of errors the Geographical Coordinates of the corners of the Six Inch sheets were computed and later published in Bulletin 13. The latitude of each station, which is necessary to an accuracy of one second of arc for the computation of the BOUGUER anomaly, could be obtained by linear interpolation, but the longitude could not.

At present, the Ordnance Survey are actively engaged in a resurvey of the country and, starting from the urban centres, new maps are being issued which have coordinates marked thereon. However, in the meantime, the only large scale maps available for a considerable area of the country will be the Six Inch series.

From the various requests received by the Institute it is apparent that other workers, not only in Geophysics, require similar information and, in order to be perhaps of some assistance to them, the methods in use at the Institute for the derivation of coordinate systems is given in this Bulletin. They have been found sufficient for most geophysical purposes but no claim is made for this being a definitive investigation.

Large Scale Maps

The basic large scale maps for Ireland are on 1: 10 560 scale and each sheet covers an area 32000 by 21000 feet. The sheets are subdivided into others on the scale of 1:2500 and a further subdivision of the latter is made for city areas on the scale of 1:1250.

These maps are on a county basis. The sheets are on a rectangular grid oriented on a prime meridian through a point known as the County Origin. For the twenty six counties comprising the Republic of Ireland, five of these origins are primary or secondary trigonometrical points, two are located in Observatories at the position of the Transit Instrument, three are monuments and sixteen are church spires or turrets. Those in the latter two categories are all in towns.

In each county a system of rectangular coordinates, in feet, known as County Coordinates was established on the County Origin and the sheets drawn up on a CASSINI-SOLDNER projection on the AIRY Spheroid.

The positioning of the sheet lines was arranged so that the number of sheets would be minimum and so in no case did an Origin fall on a sheet line. However, the distances to the sheet lines from the Origin were made in units of one hundred feet in all counties except Wicklow. These are listed in Appendix 1. The coordinates of the corners of the 1: 10 560 sheets are then in units of 100 feet, the 1: 2500 sheets - 25 feet and 1: 1250 sheets - 12.5 feet.

An example of the system is given in Figure 1 for the County Dublin.

Any point in Ireland can then be specified to a high degree of accuracy by County Coordinates which can be obtained by direct linear interpolation. It has been found from dealing with hundreds of the paper sheets at the Institute that they in general are rarely distorted from their rectangular shape though the ratio of the sides may no longer be 21:32. This can be allowed for in the interpolation.

If the limits of accuracy of the measurements on each sheet be taken as 0.2 mm, the coordinates on the 1: 10 560 scale can be obtained to within seven feet and on the 1: 2500 to within two feet. These accuracies are quite adequate for the specification of points of geophysical interest.

COUNTY DUBLIN

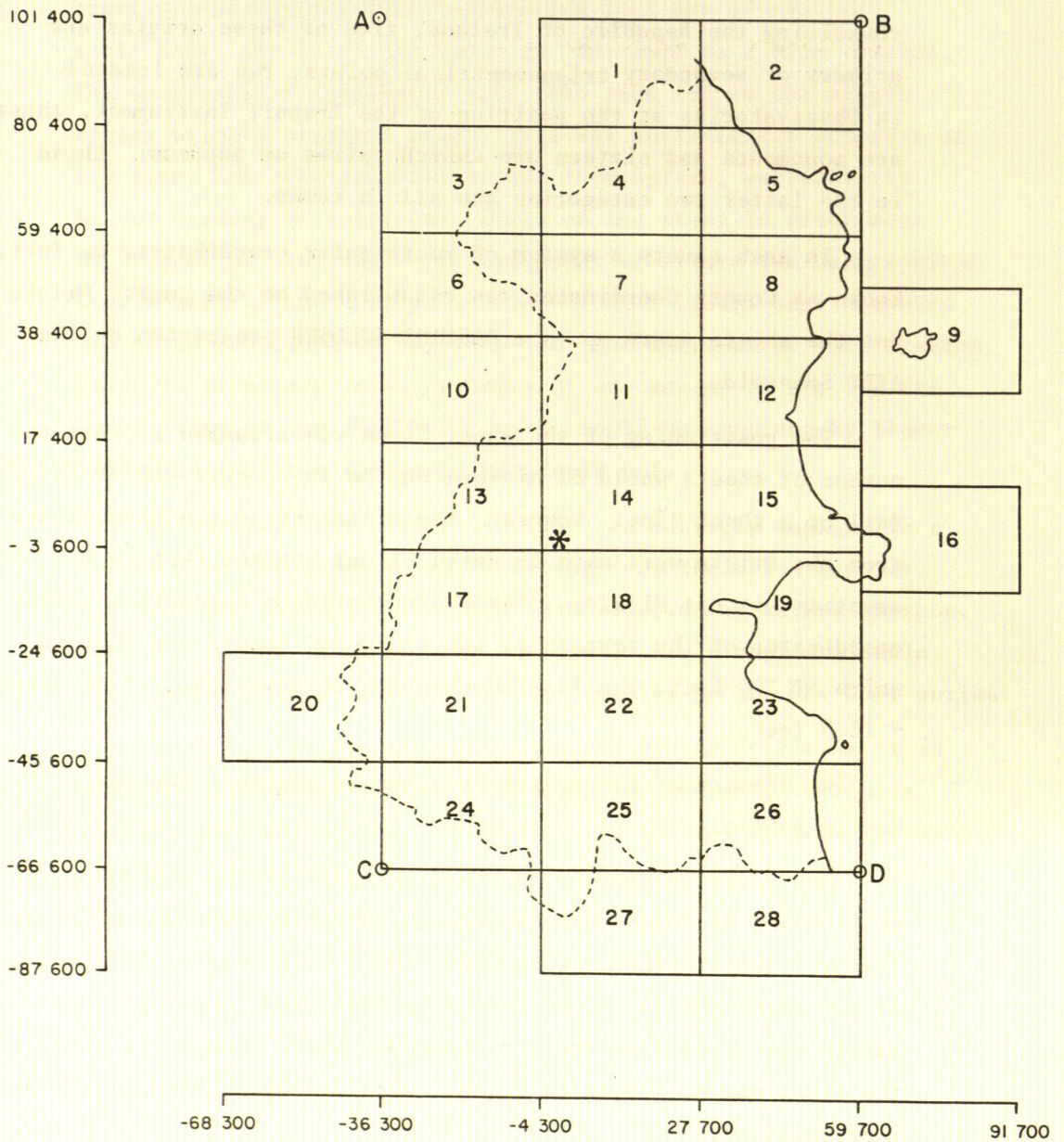


FIGURE 1: Layout of the 1:10 560 sheets for Co. Dublin with the County Coordinates for the sheet corners.

* County Origin — DUNSINK OBSERVATORY TRANSIT.

Small Scale Maps

The small scale maps of Ireland, which include the half inch to one mile "military maps" and the quarter million scale (approximately a quarter inch to one mile), are based on the 1: 63 360 scale, i.e. one inch to one mile.

Each sheet of the One Inch series measures eighteen inches by twelve inches representing 95 040 x 63 360 feet on the ground. In a similar manner to the Six Inch series, the sheets form a rectangular grid oriented on the meridian 8° west. The origin of the coordinates is located at $53^{\circ} 30'$ north on this meridian. The positioning of the sheet lines was chosen to minimise the total number of sheets but preference was given to a sheet which would conveniently enclose the city of Dublin and suburbs in the mid nineteenth century. The origin, $53^{\circ} 30'$ north 8° west lies in sheet number 98 and fixed at 27 040 feet from the west line and 27 640 feet from the south line. When it is realised that 40 feet is represented by only 0.2 mm and 640 feet by 3 mm on this scale the choice of values for the south west corner of sheet 98 is strange. This origin, lying close to the shore in Lough Ree, is not easily accessible and not marked by any monument.

Construction of the One Inch Map

The detail on the One Inch maps was taken from the Six Inch maps by reduction, but, since the latter are on a county basis some system for positioning of the reduced maps had to be devised.

The Ordnance Survey undertook this task in 1852 and as had been done in Great Britain previously, chose the BONNE projection for the One Inch map (Ordnance Survey 1953). It is inferred, from a study of a manuscript entitled 'Calculation Sheet Book for One Inch Map' in the Ordnance Survey, that the procedure was as follows.

The extremes or near extremes of the Six Inch sheet plan for each county were designated A, B, C and D (see fig. 1). The County

Coordinates of these points were corrected for the 'County Twist' which is a small correction with an average value of 15" (Bulletin 13) applied to the projection meridian. It was deduced from the adjustment of the Primary Triangulation, the results of which would then have been known prior to publication. These 'corrected' County Coordinates on the CASSINI-SOLDNER projection were transformed into Geographical Coordinates of the BONNE projection based on the Geographical Coordinates of the County Origins. The latter coordinates in most cases are "old unadjusted values" (Par. 1.8 Ordnance Survey 1953), others are not (fig. 1, Bulletin 13).

The formulae for the CASSINI-SOLDNER projection have been given in Table 1 of Bulletin 13 and those for the BONNE projection in standard textbooks and in publications of the Ordnance Survey.

A comparison has been made between the two projections for Point A of Co. Cork and given in Table 1. This point was selected because this county is the most extensive and also the County Coordinates of the point are the largest for the country as a whole. It can be seen that the difference between the two projections is indeed small and this had been found in the earlier publication (cf. p. 6, Bulletin 13) when it was suspected that the BONNE projection had been used. The small correction then applied resulted in the values given for the Geographical Coordinates being really on the BONNE projection. Confirmation of this has been obtained by J.H. Andrews (1975) from his study of Survey correspondence.

TABLE 1 Comparison of Geographical Coordinates computed on CASSINI-SOLDNER and BONNE projections with those in the Calculation Sheet Book.

Point A	County Cork	
County Coordinates	E_c	-284 000
	N_c	101 700
County Twist		-4.69"
	Latitude	Longitude
CASSINI-SOLDNER	$52^{\circ} 22' 53.01''$	$-10^{\circ} 06' 37.74''$
BONNE	$52^{\circ} 22' 53.109''$	$-10^{\circ} 06' 37.741''$
Calculation Sheet Book	$52^{\circ} 22' 53.11''$	$-10^{\circ} 06' 37.74''$

When the Geographical Coordinates for all the points A, B, C and D for each county had been computed the next procedure was to fit the various sheets together. A second transformation was then undertaken and the Geographical Coordinates transformed into One Inch Coordinates using the BONNE projection based on the origin $53^{\circ} 30'$ north 8° west.

The sample chosen is again Cork point A and is given in Table 2. There is a small disagreement in the rectangular coordinates calculated compared with those listed in the Calculation Sheet Book but the comparison can be classed as good.

TABLE 2 Comparison of One Inch Rectangular Coordinates computed on BONNE projection with those listed in the Calculation Sheet Book.

Point A.	County Cork	
	Latitude	Longitude
Geographical Coordinates	$52^{\circ} 22' 53.11''$	$-10^{\circ} 06' 37.74''$
One Inch Coordinates	E_1	N_1
Computed by standard formulae	-471 369.4	-401 388.5
As listed in Calculation Sheet Book	-471 369.3	-401 388.4

When the One Inch Coordinates for all the points A,B, C and D of each county were computed, presumably the reduced county maps were laid directly on the rectangular One Inch grid. Since each county was mapped on its own meridian the boundaries of adjacent counties theoretically cannot fit but the discrepancies may be too small to be noticeable at the one inch scale. Misfits were probably eliminated in the necessary redrawing.

Transference of a Point from a Six Inch to a One Inch Sheet

The system described for the construction of the One Inch sheets can be used to transfer a point from one series to the other and would be as follows. The County Coordinates of a point on a Six Inch sheet are deduced from a knowledge of the county sheet layout and the details of the origin; these are then converted to Geographical Coordinates which in turn are transformed into One Inch Coordinates. Knowing the One Inch grid system, the relevant sheet is obtained and the position marked using an adjustable scale. This is accurate to a foot but the whole process is laborious.

The various formulae and constants necessary to verify the above statements are available at the Institute if requested.

For ordinary purposes the method is quite impractical and it has been found that a linear transformation process using the formulae 2a and 2b, given in Appendix 2, is quite sufficient.

The accuracy depends on the size of the county and only in the counties Clare, Cork, Kerry and Wexford is it outside the range ± 10 feet, i.e. 0.05 mm at the One Inch scale.

This is then a convenient way of transforming station positions from large scale onto small scale maps knowing that the points will fall on the allotted places.

There are many reasons for using the One Inch Coordinates, the grid lines are straight and parallel to the sheet lines. The values for the sheet corners are listed and available, but if not immediately to hand can be easily deduced from a One Inch index sheet. Given the coordinates of a position, the One Inch map on which it lies can readily be ascertained and, with a scale, the location found. The principal use of the One Inch Coordinates lies in the derivation of the Geographical Coordinates which is described later.

The problem often arises of positioning a Six Inch sheet on a One Inch or Half Inch map. This is accomplished using the formulae and constants of Appendix 2 to obtain the One Inch Coordinates of two corners and then positioning these using standard scales since the coordinates are rectangular.

National Grid Coordinates

When the National Grid Coordinates system was introduced into Ireland the origin was chosen the same as that for the One Inch map and in order to keep all the coordinates positive the origin was designated 200 000, 250 000. The projection however was not BONNE but a TRANSVERSE MERCATOR, not the UNIVERSAL TRANSVERSE MERCATOR (Ordnance Survey, 1953).

Sometime later it was decided that National Grid Coordinates should be superimposed on the Half Inch maps. The Geographical Coordinates of the corners were known from the One Inch sheets which had been derived on the BONNE projection. These were transformed on a TRANSVERSE MERCATOR projection to National Grid Coordinates and straight lines drawn by interpolation at 10 km intervals.

Since the difference between the BONNE and the TRANSVERSE MERCATOR projection is small and in Ireland the One Inch origin and the National Grid origin is the same an interconversion is possible and can be achieved by the following formulae.

$$\text{N.G. Easting} = 0.3048 (E_1 + 4E_1^3 \times 10^{-16}) + 200\,000 \quad (\text{formula 1a})$$

$$\text{N.G. Northing} = 0.3048 (N_1 + 1.1 E_1^2 N_1 \times 10^{-15}) + 250\,000 \quad (\text{formula 1b})$$

where E_1 and N_1 are the One Inch Coordinates. The accuracy of these formulae is about ± 1 m.

As an example, the south west corner of the Half Inch sheet 21 has One Inch Coordinates -407 200, -597 880. These are transformed by the above formulae to National Grid Coordinates 075 877.2, 067 732.5 which can be compared with those printed on the sheet, namely, 075 877, 067 733.

This method is not very convenient, and because the differences between the various rectangular systems have been shown to be small, the National Grid Coordinates for a point on a Six Inch sheet can be obtained directly by linear formulae from County Coordinates. This is accomplished by using the formulae and constants of Appendix 3. The accuracy is ± 2 metres.

Latitude and Longitude

The direct derivation of the Geographical Coordinates of a point on a Six Inch sheet which would be consistent with the One Inch map is by means of the BONNE projection already described. This, however, is not convenient. The County Coordinates have first to be corrected for the 'County Twist' and each county, having its own origin, has a series of constants. The accuracy as shown in Table 1 is $\pm 0.01''$ which is much greater than normally required. Instead, a more convenient method, and one followed at the Institute, is to transform the County Coordinates to One Inch Coordinates and then to compute on the BONNE projection using the equation given in Appendix 4. The correction for the 'County Twist' is included in this transformation. The accuracy is of the order $\pm 0.2''$ for all except the larger counties already referred to.

Because of the projection the Geographical Coordinates deduced by the above methods will not agree with those linearly interpolated from the scales engraved on the One Inch sheets. The difference is noticeable on the Half Inch and Quarter Million series, which are derived from the One Inch by reduction.

Transformation of Latitude

The transformation of Geographical Coordinates has been given in Bulletin 35. In gravity surveying the latitude used for the derivation of the BOUGUER ANOMALY is that on the International Spheroid. A simple formula is used at the Institute to transform from AIRY latitude to latitude on the International Spheroid European Datum 1950 (ED50) as follows:-

$$\phi_{ED50}^{\circ} = 0.999\ 8722\ \phi_{AIRY}^{\circ} + 0.007\ 977.$$

The Coordinates Systems in use in Ireland

The Coordinate Systems in current use in Ireland are five in number namely:-

- a) County Grid Coordinates (feet).
- b) National Grid Coordinates (metres).
- c) Geographical Coordinates on the AIRY spheroid.
- d) Geographical Coordinates on the INTERNATIONAL spheroid.
European Datum 1950.
- e) Universal Transverse Mercator Coordinates zone 29.

The transformations from a) to b) and c) can be performed as given in Appendices 3 and 4 respectively, and those from c) to d), and c) to e) have been given in Bulletin 35.

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- Appendix 1 County Origins.
- Appendix 2 Transformation of County Coordinates
 to One Inch Coordinates.
- Appendix 3 Transformation of County Coordinates
 to National Grid Coordinates.
- Appendix 4 Transformation of One Inch Coordinates
 to Geographical Coordinates (AIRY).

The derivation of the constants and formulae in
the Appendices are available for inspection at the Institute.

Appendix I

County Origins

	Sheet Number	E_o	N_o
Carlow	23	14 600	20 800
Cavan	20	24 400	3 300
Clare	33	27 200	9 200
Cork	31	28 000	3 300
Donegal	53	13 000	5 600
Dublin	22	4 300	3 600
Galway	94	11 500	17 600
Kerry	29	13 200	5 800
Kildare	22	23 600	5 400
Kilkenny	19	20 400	11 500
Leitrim	31	11 000	16 000
Laois	13	8 000	7 000
Limerick	5	15 500	4 600
Longford	13	28 000	14 800
Louth	7	12 100	11 900
Mayo	78	22 900	14 800
Meath	36	22 100	13 100
Monaghan	9	22 000	7 000
Offaly	17	9 000	9 500
Roscommon	39	26 800	9 000
Sligo	26	29 000	17 200
Tipperary	61	3 000	10 500
Waterford	6	17 100	15 800
Westmeath	19	11 000	6 300
Wexford	42	6 200	17 800
Wicklow	28	23 400	20 950

E_o is the distance in feet from the western edge to the origin.

N_o is the distance in feet from the southern edge to the origin.

Appendix 2 Transformation of County Coordinates to One Inch
Coordinates

$$\text{One Inch Easting Coordinate} = E_c J + N_c K + L \quad \text{Formula 2a}$$

$$\text{One Inch Northing Coordinate} = N_c J - E_c K + M \quad \text{Formula 2b}$$

E_c and N_c are County Coordinates and the constants J, K, L and M for each county are:-

	J	K	L	M
Carlow	0.999 854	-0.016 946	+271 115	-319 816
Cavan	0.999 959	-0.009 074	+137 738	+180 867
Clare	0.999 907	+0.013 665	-216 809	-237 424
Cork	0.999 934	+0.011 640	-188 559	-506 427
Donegal	0.999 992	-0.003 790	+ 54 967	+529 836
Dublin	0.999 725	-0.023 446	+362 686	- 37 049
Galway	0.999 891	+0.014 772	-230 489	- 81 404
Kerry	0.999 721	+0.023 682	-381 395	-444 310
Kildare	0.999 882	-0.015 321	+238 821	-123 154
Kilkenny	0.999 944	-0.010 513	+166 074	-309 001
Leitrim	0.999 999	+0.001 192	- 20 208	+163 144
Laois	0.999 950	-0.009 768	+153 422	-169 493
Limerick	0.999 952	+0.008 744	-139 398	-306 900
Longford	0.999 996	-0.002 885	+ 43 431	+ 84 377
Louth	0.999 744	-0.022 605	+343 892	+189 435
Mayo	0.999 837	+0.018 046	-280 536	+131 874
Meath	0.999 849	-0.016 789	+262 397	+ 21 099
Monaghan	0.999 892	-0.014 654	+220 522	+274 739
Offaly	0.999 969	-0.007 384	+113 628	- 82 986
Roscommon	0.999 997	+0.002 524	- 41 288	+ 47 086
Sligo	0.999 972	+0.006 284	- 97 882	+246 791
Tipperary	0.999 997	-0.001 647	+ 25 566	-359 629
Waterford	0.999 968	-0.005 902	+ 93 660	-442 017
Westmeath	0.999 954	-0.009 310	+143 780	+ 9 583
Wexford	0.999 799	-0.020 061	+321 723	-429 159
Wicklow	0.999 766	-0.021 558	+338 536	-191 073

Appendix 3 Transformation of County Coordinates to National Grid Coordinates

$$\text{N.G. Easting} = E_c E + N_c F + G \quad \text{Formula 3a}$$

$$\text{N.G. Northing} = N_c E - E_c F + H \quad \text{Formula 3b}$$

E_c and N_c are County Coordinates and the constants E, F, G and H for each county are:-

	E	F $\times 10^{-3}$	G	H
Carlow	0.304 780	-5.140 50	282 638.9	152 511.6
Cavan	0.304 797	-2.773 20	241 983.5	305 130.5
Clare	0.304 803	+4.145 04	133 912.5	177 626.8
Cork	0.304 812	+3.506 84	142 521.2	95 623.8
Donegal	0.304 809	-1.160 33	216 754.6	411 502.9
Dublin	0.304 766	-7.145 22	310 552.9	238 705.6
Galway	0.304 803	+4.498 23	129 739.8	225 184.8
Kerry	0.304 781	+7.153 57	83 740.8	114 549.6
Kildare	0.304 790	-4.658 71	272 794.9	212 460.0
Kilkenny	0.304 794	-3.185 87	250 620.4	155 812.7
Leitrim	0.304 802	+0.364 80	193 840.7	299 726.8
Laois	0.304 795	-2.967 98	246 764.0	198 336.5
Limerick	0.304 801	+2.644 47	157 509.9	156 452.8
Longford	0.304 802	-0.881 52	213 237.7	275 718.5
Louth	0.304 766	-6.908 76	304 823.4	307 748.0
Mayo	0.304 787	+5.517 56	114 486.8	290 200.3
Meath	0.304 785	-5.123 78	279 982.4	256 431.4
Monaghan	0.304 787	-4.486 99	267 216.6	333 745.9
Offaly	0.304 799	-2.245 83	234 634.8	224 704.8
Roscommon	0.304 804	+0.770 87	187 415.4	264 353.0
Sligo	0.304 805	+1.926 03	170 165.5	325 223.8
Tipperary	0.304 804	-0.499 72	207 792.8	140 382.8
Waterford	0.304 799	-1.781 06	228 548.3	115 269.3
Westmeath	0.304 794	-2.838 92	243 825.0	252 921.0
Wexford	0.304 777	-6.075 70	298 066.5	119 175.6
Wicklow	0.304 777	-6.548 40	303 191.3	191 752.8

$\times 10^{-3}$

Appendix 4 Transformation of One Inch Coordinates to Geographical Coordinates (AIRY)

$$\theta^{\circ} = (2.7635025 - 6.321765m \times 10^{-6}) m \times 10^{-6} \text{ to } -0.023984$$

Geographical Coordinates

$$\phi^{\circ} = (2.7635025 \times 10^{-6} - 6.321765 \times 10^{-16} \times m) m - 0.023984$$

$$\lambda^{\circ} = 7.38318(15516209.9 - E_1 \tan C / \delta m) \times \sqrt{(1 - 6.67054 \times 10^{-3} \sin^2 \phi)} - 8$$

$$\text{where } C = \tan^{-1} \left(\frac{E_1}{15519209.9 - \tan C = E / (R_0 - N)} \right)$$

$$R_0 = 15516209.9$$

$$m = 19545751.7 + N_1 - E_1 \tan C / \delta m = N - E \tan C / 2$$

$$m = 19454751.7 + \delta m$$

E_1 and N_1 are the One Inch Coordinates.

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