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The Defense Mapping Agency

DMA TM 8358.1

DMA TECHNICAL MANUAL

DATUMS, ELLIPSOIDS, GRIDS, AND GRID REFERENCE SYSTEMS

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DEFENSE MAPPING AGENCY TECHNICAL MANUAL 8358.1

DATUMS, ELLIPSOIDS, GRIDS, AND GRID REFERENCE SYSTEMS

Abstract: This manual describes the basic principles of the Military Grid Reference System and the non-standard reference systems. It describes the method for determining references on maps and charts at scales of 1:1,000,000 and larger. It contains identifications for the grid zone designations and for the 100,000 meter squares of the Universal Transverse Mercator Grid and the Universal Polar Sterographic Grid. It also contains the specifications and grid identifications for the various non-standard grids. It provides diagrams and textual information for delineating geodetic datums and ellipsoids.
Subject Terms: Position location, military grid, geodetic datum, coordinate reference system, ellipsoid, spheroid, graticule, chart, projection.

DEFENSE MAPPING AGENCY

MISSION:

To enhance national security and support the Office of the Secretary of Defense, the Joint Chiefs of Staff, Unified and Specified Commands, Military Departments, and other users, by producing and distributing timely and tailored mapping, charting, and geodetic products, services, and training, and advising on such matters. To provide nautical charts and marine navigational data to worldwide merchant marine and private vessel operators. To maintain liaison with civil agencies and other national and international scientific and other mapping, charting, and geodetic activities.

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DEFENSE MAPPING AGENCY TECHNICAL MANUAL 8358.1

DATUMS, ELLIPSOIDS, GRIDS, AND GRID REFERENCE SYSTEMS

FOREWORD

1. This manual states current authoritative guidance for the use and portrayal of grids and grid reference systems information as applicable to maps and charts compiled for the United States Department of Defense (DoD).
2. This publication contains no copyrighted material and has been approved for public release. Distribution is unlimited. DoD users may order copies from the Defense Mapping Agency Combat Support Center, ATTN: PMSR, Washington, D.C. 20315-0020. All other requests should be directed to the National Technical Information Center, Cameron Station, Alexandria, VA 22314-6145.

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DMA TM 8358.1

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* Requires periodic update and revision.

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CHAPTER I

GENERAL

1-1 AUTHORITY.

This document is issued under the authority delegated by DoD Directive 5105.40, subject: Defense Mapping Agency (DMA), 12 December 1988.

1-2 REFERENCES.

1-2.1 The DMA TM 83581 series replaces the DA TM 5-241 series of manuals.
1-2.2 JCS-MOP 88, Position Reference Procedures, 8 May 1981.
1-2.3 STANAG 2211, subject: Geodetic Datums, Ellipsoids, Grids, and Grid References.
1-2.4 STANAG 3676, subject: Marginal Information on Land Maps and Aeronautical Charts.
1-2.5 QSTAG 544, subject: Geodetic Datums, Spheroids, Grids, and Grid References.
1-2.6 IHO Circular Letter 9, International Horizontal Datum for Chart Reference, 15 March 1983.
1-2.7 IHO Circular Letter 28, Transformation Notes, WGS-84, 15 July 1988.
1-2.8 IHO Circular Letter 46, International Horizontal Datum for Chart Reference, 16 December 1983.
1-2.9 IHO Circular Letter 18, Indication on Charts of Relationship of Horizontal Datum to Worldwide and Other Datums, 17 May 1984.
1-2.10 IHO Circular Letter 46, Indication on Charts of Relationship of Horizontal Datum to Worldwide and Other Datums, 14 December 1984.
1-2.11 DMA TM 83581.2 The Universal Grids: Universal Transverse Mercator (UTM) and Universal Polar Stereographic (UPS).
1-2.12 DMA TR 8350.2 (and supplements) Department of Defense World Geodetic System 1984.

1-3 PURPOSE.

1-3.1 This manual provides guidance to DoD Mapping, Charting and Geodesy (MC&G) production elements, product users, and system developers on the application of datums, ellipsoids, grids, and grid reference systems within the DoD.
1-3.2 It describes the standard methods for selecting and portraying grids orf maps and charts at scales of 1:1,000,000 and larger. Descriptions are based on the following categories.
1-3.2.1 Topographic Maps.
1-3.2.2 Hydrogrophic Charts.
1-3.2.3 Aeronautical Charts.

1-4 SCOPE.

1-4.1 This manual specifies the use of geodetic datums, ellipsoids, grids and grid reference systems used in the production of maps and charts for the DoD.
The Universal Transverse Mercator an d Universal Polar Stereographic grids, the Military Grid Reference System, and nonstandard grid reference systems are described.
1-4.2 Detailed instructions and formats for grid depictions and labeling, grid margin data, declination data, etc. are contained in the DMA product specifications for approved topographic, hydrographic, and' aeronautical products.

1-5 UTILIZATION.

1-5.1 TM 83581.1 is to be used by DoD MC&G production elements, product users, and DoD system developers in the application of datums, ellipsoids, grids, and grid reference systems.
1-5.2 Users are cautioned that the information contained herein applies to current and future MC&G production, and does not necessarily apply to products that are currently available through the DoD supply system.

1-6 DEFINITIONS.

1-6.1 Major Grid. The primary grid or grids on a map or chart.
1-6.2 Military Grid Reference System (MGRS). The alphanumeric position reporting system used by U.S. military. A full description is provided in Chapter 3.
1-6.3 Nonstandard Grids. Grids other than UTM and UPS, such as Ceylon Belt, India Zone IIA, West Malaysian RSO (Metric) Grid, etc.
1-6.4 Operational Grid. A grid in current operational use. Generally this would be the preferred grid but could be a previously prescribed grid.
1-6.5 Overlapping Grid. A major grid from a neighboring area primarily intended to facilitate military surveying anti fire-control.
1-6.6 Preferred Grid. The grid designated by the DoD for production of new maps, charts, and digital geographic data; and shown on the "Index to Preferred Grids, Datums, and Ellipsoids Specified for New Mapping" (Appendix D).
1-6.7 Prescribed Grid. The grid that is locally prescribed, by the country of origin or military commander.
1-6.8 Primary Grid. The major, or principal, grid on a map or chart.
1-6.9 Secondary Grid. Any grid, other than the primary grid, required for combined operations application. Tick marks along the neat lines are the preferred method of portrayal. Such grids should remain on the maps or charts so long as the secondary grid remains in use.
1-6.10 Standard Grids. The Universal Transverse Mercator (UTM) grid and the Universal Polar Stereographic (UPS) grid.
1-6.11 World Geographic Reference System (GEOREF). A worldwide position reference system that may be applied to any map or chart graduated in latitude and longitude regardless of projection. It provides a method of expressing positions in a form suitable for reporting and plotting. The primary use is for interservice and interallied reporting of aircraft and air target positions.
1-6.12 Other Key Terms.

1-6.12.1 Bleeding Edge. That edge of a map or chart on which cartographic detail is extended beyond the neatline to the edge of the sheet.
1-6.12.2 Coordinate Reference Notation Grid coordinates are given in terms of linear in meters. Geographic coordinates are given in terms of angular measurement, usually in degrees, minutes, and seconds but occasionally in grads.
1-6-12.3 Datum. As used in this manual, datum refers to the geodetic or horizontal datum. The classical datum is defined by a minimum of five elements giving the position of the origin (two elements), the orientation of the network (one element), and the parameters of a reference ellipsoid (two elements). More recent definitions express the position and orientation as functions of the deviations in the meridian and in the prime vertical, the geoidellipsoid separation, and the parameters of a reference ellipsoid. The World Geodetic System is a geocentric system that provides a basic reference frame and geometric figure for the earth, models the earth gravimetrically, and provides the means for relating positions on various datums to an earth-centered, earth fixed coordinate system.
1-6.12.4 Easting. Eastward (that is left to right) reading of grid values on a map.
1-6.12.5 Ellipsoid. An ellipsoid is a mathematical figure generated by the revolution of of an ellipse about one of its axes. The ellipsoid that approximates the geoid is an ellipse rotated about its minor axis, or an oblate spheroid.
1-6.12.6 False Easting. A value assigned to the origin of eastings, in a grid coordinate system, to avoid the convenience of using negative coordinates.
1-6.12.7 False Northing. A value assigned to the origin of northings, in a grid coordinate system, to avoid the inconvenience of using negative coordinates.
1-6.12.8 Geoid. The equipotential surface in the gravity field of the Earth which approximates the undisturbed mean sea level extended continuously through the continents. The direction of gravity is perpendicular to the geoid at every point. The geoid is the surface of reference for astronomic observations and for geodetic leveling.
1-6.12.9 Graticule. A network of lines representing parallels of latitude and meridians of longitude forming a map projection.
1-6.12.10 Grid. Two sets of parallel lines intersecting at right angles and forming squares; a rectangular Cartesian coordinate system that is superimposed on maps, charts, and other similar representations of the earth's surface in an accurate and consistent manner to permit identification of ground locations with respect to other locations and the computation of direction and distance to other points.
1-6.12.11 Isogonic Line. A line drawn on a map or chart joining points of equal magnetic declination for a given time. The line connecting points of zero declination is the agonic line. Lines connecting points of equal annual change are isopors. The Magnetic Variation chart for the current 5-year epoch is available from the DMACSC.
1-6.12.12 Loxodrome. A line on the surface of the Earth cutting all meridians at the same angle, a rhumb line.
1-6.12.13 Map Projection. An orderly system of lines on a plane representing a corresponding sytem of imaginary lines on an adopted terrestrial datum surface. A map projection may be derived by geometrical construction or by mathematical analysis.
1-6.12.14 Neatline. The lines that bound the body of a map, usually parallels and meridians (but may be conventional or arbitrary grid lines); also called sheet lines.

1-6.12.15 Northing. Northward (that is from bottom to top) reading of grid values on a map.
1-6.12.16 Sheroid. A mathematical figure closely approaching the geoid in form and size. Ellipsoid will be used in this manual.

1-7 REFERENCE SYSTEMS.

1-7.1 Rectangular grid reference systems are usually shown on military maps and chart at scales of 1:1,000,000 and larger. Maps and charts at all scales show the geographic graticule. Maps and aeronautical charts at 1:250,000 scale and smaller show the GEOREF.
1-7.2 The Military Grid Reference System is described in Chapter 3.
1-7.3 Grid reference systems used with operational nonstandard grids are described in Chapter 4.
1-7.4 The geographic coordinates are described in Chapter 5.

1-8 STANDARD AND NONSTANDARD GRIDS.

1-8.1 The standard grid for polar areas north of 84° north, and south of 80° south, is the Universal Polar Stereographic (UPS) grid.
1-8.2 Between 84°north and 80° south, the standard grid is the Universal Transverse Mercator (UTM) grid. Other grid systems are being phased out. The long term objective is to convert the mapping of all areas of the world to UTM and UPS grids.
1-8.3 Normally, grids are not portrayed on maps at scales smaller than 1:1,000,000.

1-9 MULTIPLE GRIDS.

The use of military grids presents complex conditions in junction areas, i.e., grid zone junctions within a grid system, grid junctions between various grid systems, datum junctions, and junctions between ellipsoids. Despite this complexity, these conditions lend themselves to a uniform graphical treatment of the grids with differences in grid orientation and grid color, labels, and values. The treatment of grids under various junction conditions is prescribed in later chapters of this manual.

1-10 OVERLAPPING GRIDS.

Maps at scales of 1:100,000 and larger, falling within approximately 40 kilometers of a grid junction, datum junctions or ellipsoid junction, usually show the adjacent (overlapping) grid by ticks and values around the neatline. In some instances, a coordinate conversion note may be used instead of an overlapping grid.

1-11 EXTENDED GRIDS.

An extended grid is form of overlapping grid used on city maps. It provides total coverage of a map on a single grid when a portion of the map falls on an adjacent grid. The major grid is extended to cover the adjacent area and is shown by full lines.

1-12 GRID AND DATUM RELATED MARGINAL NOTES.

Marginal notes on maps and charts should include projection, ellipsoid, grid zone or belt, horizontal datum, and magnetic declination data. Specific treatment of these items on each product is covered in the various product specifications.

1-13 SUPERCESSION.

This document supercedes DMA 8358.1, Preliminary Edition.

CHAPTER 2
DATUMS, ELLIPSOIDS, PROJECTIONS AND MILITARY GRIDS

2-1 GENERAL.

2-1.1 The Earth is not a sphere, but an ellipsoid, flattened slightly at the poles and bulging somewhat at the Equator. The ellipsoid is used as a surface of reference for the mathematical reduction of geodetic and cartographic data.
2-1.2 A map projection is the systematic drawing of lines representing the meridians and parallels (the graticule) on a flat surface. Different projections have unique characteristics and serve differing purposes. They are depicted by projecting the graticule of the ellipsoid onto a plane; the intersections of the graticule are computed in terms of the ellipsoid.
2-1.3 U.S. Military maps use the sexagesimal system of angular measurement (the division of a full circle into 360°) for designating the values of the graticule. A degree is divided into 60 minute, and each minute into 60 seconds. Parallels are numbered north and south from O° at the equator to 90° at the poles. Meridians are numbered east and west from O° at the prime meridian to a common 180° meridian. The prime meridian used for U.S. Military mapping and charting is related to the Bureau International de I'Heure defined Zero Meridian, located near Greenwich, England. Some foreign produced maps may use the centesimal (decimal) system of angular measurement (the division of a full circle into 400 grads). A grad (or gon) is divided into 100 centigrade (grad minutes), and each centigrad into 100 deci-milligrads (grad seconds). Other prime meridians may be used in non-U.S. mapping.
2-1.4 Grids are applied to maps to provide a rectangular system for referencing and making measurements. There is a definite relationship between the grid and the graticule so that a corresponding geographic position can be determined for each grid position.

2-2 HORIZONTAL DATUMS

The identification, pertinent descriptive information, parameters, and attendant explanatory footnotes for some geodetic datums currently in use are contained in table 1. The datums preferred for use in the production of new and revised topographic maps, joint operations graphics, and selected large scale nautical charts are shown in Appendix D which also graphically depicts their areas of application.

2-3 TRANSFORMING COORDINATES FROM ONE HORIZONTAL DATUM TO ANOTHER HORIZONTAL DATUM.

2-3.1 Coordinates may be transformed from one geodetic datum to another geodetic datum by using the Abridged Molodenskiy Datum Transformation Formulas:

$$\Delta\phi'' = [-\Delta X \sin\phi \cos\lambda - \Delta Y \sin\phi \sin\lambda + \Delta Z \cos\phi + (a\Delta f + f\Delta a)\sin 2\phi]/[R_M \sin 1'']$$

$$\Delta\lambda'' = [-\Delta X \sin\lambda + \Delta Y \cos\lambda]/[R_N \cos\phi \sin 1'']$$

$$\Delta H = \Delta X \cos\phi \cos\lambda + \Delta Y \cos\phi \sin\lambda + \Delta Z \sin\phi + (a\Delta f + f\Delta a)\sin^2\phi - \Delta a$$

where

Phi = geodetic latitude.
Lambda = geodetic longitude
H = the distance of a point above or below the ellipsoid measured along the
ellipsoid normal through the point.

NO.	DATUM	AREA	DATUM POINT	LATITUDE (φ) LONGITUDE (λ)	ELLIPSOID
1	World Geodetic System 1984	Sino-Soviet Bloc, S.W. Asia, Hydrographic, Aeronautical	Earth center of mass		World Geodetic System 1984[1]
2	North American 1983	Canada, Cuba, U.S. and Possessions in the Caribbean North Greenland	Earth center of mass		GRS 80
3	North American 1927	North America	Meades Ranch	39°13′26.686″N 98°32′30.506″W	Clarke 1866
4	Qornoq	Greenland	Station 7008	64°31′06.27″N 51°12′24.86″W	International
5	Hjorsey 1955	Iceland	Hjorsey	64°31′29.260″N 22°22′05.840″W	International
6	Naparima	Trinidad and Tobago	Naparima	10°16′44.86″N 61°27′34.62″W	International
7	Provisional South American 1956	Bolivia, Chile, Columbia, Ecuador, Peru, the Guianas, Venezuela	La Canoa	8°34′17.17″N 63°51′34.88″W	International
8	Corrego Alegre	Brazil	Corrego Alegre	19°50′15.14″S 48°57′42.75″W	International
9	Chua Astro	Paraguay	Chua Astro (Brazil)	19°45′41.16″S 48°06′07.56″W	International
10	Campo Inchauspe	Argentina	Campo Inchauspe	35°58′16.56″S 62°10′12.03″W	International
11	Yacare	Uruguay	Yacare	30°35′53.68″S 57°25′01.30″W	International
12	European 1950	Europe, Middle East, North Africa	Potsdam, Helmertturm	52°22′51.4456″N 13°03′58.9283″E	International
13	Ordnance Survey of Great Britain 1936	Great Britain, Northern Ireland	[2]		Airy

Table I. Geodetic Datums Used in Map Production (page 1 of 3.)

14	Ireland 1965	Ireland	[2]		Modified Airy
15	Merchich	Morocco	Merchich	33°26′59.672″N 7°33′27.295″W	Clarke 1880[3]
16	Voirol	Algeria, Tunisia	Voirol Observatory	36°45′07.9″N 3°02′49.45″E	Clarke 1880[3]
17	Adindan	Sudan, Ethiopia	Adindan Z_u	22°10′07.110″N 31°29′21.608″E	Clarke 1880[3]
18	Sierra Leone 1960	Sierra Leone	D.O.S. Astro SLX2	8°27′17.6″N 12°49′40.2″W	Clarke 1880[3]
19	Liberia 1964	Liberia	Robertsfield Astro	6°13′53.02″N 10°21′35.44″W	Clarke 1880[3]
20	Ghana	Ghana	G.C.S. 121 Leigon	5°38′52.27″N 0°11′46.08″W	War Office[4] (McCaw)
21	Nigeria	Nigeria	Minna	9°38′08.87″N 6°30′58.76″E	Clarke 1880[3]
22	Arc 1950	Southern Africa	Buffelsfontein	33°59′32.00″S 25°30′44.622″E	Clarke 1880[3]
23	Tananarive (Antananarivo) Obsv. 1925	Malagasy Rep.	Tananarive (Antananarivo) Obsv.	18°55′02.10″S 47°33′06.45″E	International
24	Tokyo	Japan	Tokyo Obsv.	35°39′17.515″N 139°44′40.502″E	Bessel
25	Hu-Tzu-Shan	Taiwan	Hu-Tzu-Shan	23°58′32.340″N 120°58′25.975″E	International
26	Luzon	Philippines	Balanacan	13°33′41.000″N 121°52′03.000″E	Clarke 1866
27	Indonesia 1974	Indonesia	Padang	00°56′38.414″S 100°22′08.804″E	GRS 67
28	Australian Geodetic	Australia	Johnston Memorial Cairn	25°56′54.5515″S 133°12′30.0771″E	Australian National (GRS 67)
29	Geodetic Datum 1949	New Zealand	Papatahi Trig Station	41°19′08.900″S 175°02′51.000″E	International
30	Guam 1963	Marianas Islands	Togcha or Lee 7	13°22′38.490″N 144°45′51.560″E	Clarke 1866
31	Local Astro[5]				Various
32	Camp Area Astro	Antarctica	Camp Area Astro	77°50′52.521″S 166°40′13.753″E	International

Table 1. Geodetic Datums Used in Map Production – continued.

$\Delta\phi$, $\Delta\lambda$, ΔH = corrections to transform the geodetic coordinates from the input datum to the output datum (output minus input).

ΔX, ΔY, ΔZ = shifts between ellipsoid centers from the input datum to the output datum.

a = semi-major axis of the input ellipsoid.

f = flattening of the input ellipsoid.

Δa, Δf = differences between the parameters of the input ellipsoid and the output ellipsoid (output minus input).

e = eccentricity.

$$e^2 = 2f - f^2$$

R_M = radius of curvature in the meridian. (computed from input ellipsoid)

$$= a(1 - e^2)/(1 - e^2\sin^2\phi)^{3/2}$$

R_N = radius of curvature in the prime vertical. (computed from input ellipsoid)

$$= a/(1 - e^2\sin^2\phi)^{1/2}$$

$$\sin 1'' = (0.48481\ 36811)(10^{-5})$$

Table 1: (page 3 - footnotes):

FOOTNOTES-GEODETIC DATUMS FOR MAP PRODUCTION

3. The World Geodetic System (WGS) is not referenced to a single datum point. represents an ellipsoid whose placement, orientation, and dimensions best fit the Earth's equipotential surface which coincides with the geoid. The system was developed from a worldwide distribution of terrestrial gravity measurements and geodetic satellite observations. Several different ellipsoids have been used in conjunction with the various date WGS determinations. The dimensions of the WGS 72 Ellipsoid are:
   a = 6,378,135 meters
   f = 1/298.26
   The dimensions of the WGS 84 Ellipsoid are:
   a = 6,378,137 meters
   f = 1/298.25722 3563
4. This datum is not defined in terms of an origin. It results from a retriangulation of the area to a number of points whose latitude and longitude were known with respect to Greenwich.
5. The dimensions of the Clarke 1880 Ellipsoid adopted by different countries vary in accordance with which of Clarke's original dimensions are used: (a, b) or (a, f), or which foot-meter relationship is used to convert the units from feet to meters. In the area referenced to Arc 1950 datum, the dimensions adopted are:
   Semimajor axis: a = 6,378,249.145326 meters
   Semiminor axis: b = 6,356,514.966721 meters
   The above figures yield:
   Flattening: f = 1/293.4663076
   In the areas of Merchich and Voirol datum, the dimensions adopted are:
   a = 6,378,249.2 meters
   b = 6,356,515.0 meters
   and
   f = 1/293.46598
   The values adopted by the Department of Defense are:
   a = 6,378,249.145 meters
   f = 1/293.465
   The above figures yield:
   b = 6,356,514.8696 meters
6. Dimensions of the War Office Ellipsoid derived by G. T. McCaw (1924) are:
   a = 6,378,300.58 meters
   f = 1/296.
7. Local Astro refers to several independently determined datum origins or to areas where maps are positioned by a network of astronomic positions that are not interconnected.

$\Delta\phi$, $\Delta\lambda$, ΔH = corrections to transform the geodetic coordinates from the input datum to the output datum (output minus input).

ΔX, ΔY, ΔZ = shifts between ellipsoid centers from the input datum to the output datum.

a = semi-major axis of the input ellipsoid.

f = flattening of the input ellipsoid.

Δa, Δf = differences between the parameters of the input ellipsoid and the output ellipsoid (output minus input).

e = eccentricity.

$e^2 = 2f - f^2$

R_M = radius of curvature in the meridian. (computed from input ellipsoid)
$= a(1 - e^2)/(1 - e^2\sin^2\phi)^{3/2}$

R_N = radius of curvature in the prime vertical. (computed from input ellipsoid)
$= a/(1 - e^2\sin^2\phi)^{1/2}$

$\sin 1'' = (0.48481\ 36811)(10^{-5})$

Table 1: Geodetic Datums Used in Map Production - End

2-3.2 Table 2 (Molodenskiy Transformation Constants to convert from local datum to WGS 84) lists the Delta X, Delta Y, Delta Z, Delta a, and Delta f to transform coordinates from the various datums shown in Appendix D to WGS 84. Values for a and f are listed with figure 1.
2-3.3 The direction of the transformation may be reversed by changing the signs of Delta X, Delta Y, Delta Z, Delta a, and Delta f. Note also that R_m and R_n must be computed with respect to the input ellipsoid.
2-3.4 Transformation procedures and constants are published in DMA TR 8350.2, Department of Defense World Geodetic System 1984.

2-4 ELLIPSOIDS.

2-4.1 Several ellipsoids are presently used in U.S. Military mapping. The goal is to eventually refer all positions to the World Geodetic System (WGS), which has a specific set of defining parameters, or to a WGS compatible ellipsoid. Ellipsoids may be defined by a combination of algebraically related dimensions such as the semi-major and semi- minor axes or the semi-major axis and the flattening. Figure 1 illustrates the defining elements and lists the dimensions of the ellipsoids used by the Defense Mapping Agency.
2-4.2 Appendix D (index of Preferred Grids, Datums, and Ellipsoids Specified for New Mapping) identifies the extent of currently effective ellipsoids.

2-5 PROJECTIONS

2-5.1 The projections used as the framework of all U.S. Military maps and charts have a common characteristic in that they are conformal. Conformality indicates that small areas retain their true shape; angles closely approximate their true values; and, at any point, the scale is the same in all directions.
2-5.2 Certain projections are prescribed for U.S. Military topographic mapping and charting that shows military grids:
2-5.2.1 Maps at scales of 1:500,000 and larger for areas between 80° south and 84° north, and some hydrographic charts at 1:50,000 and larger, are based on the Transverse Mercator Projection.

MOLODENSKIY TRANSFORMATION CONSTANTS
LOCAL DATUM TO WGS 84

Datum	ELLIPSOID	ΔX (m)	ΔY (m)	ΔZ (m)	Δa	Δf x 10⁴
1. North American 1927	Clarke 1866				−69.4	−0.37264 639
except Alaska		−8	160	176		
Alaska		−5	135	172		
2. Old Hawaiian	Clarke 1866	61	−285	−181	−69.4	−0.37264 639
3. Qornoq	International	164	138	−189	−251	−0.14192 702
4. Hjorsey 1955	International	−73	46	−86	−251	−0.14192 702
5. Provisional South American 1956	International				−251	−0.14192 702
Bolivia		−270	188	−388		
Chile		−270	183	−390		
Colombia		−282	169	−371		
Ecuador		−278	171	−367		
Guyana		−298	159	−369		
Venezuela		−295	173	−371		
Peru		−279	175	−379		
6. Corrego Alegre	International	−206	172	−6	−251	−0.14192 702
7. Chua Astro	International	−134	229	−29	−251	−0.14192 702
8. Campo Inchauspe	International	−148	136	90	−251	−0.14192 702
9. Yacare	International	−155	171	37	−251	−0.14192 702
10. European 1950	International				−251	−0.14192 702
except Iberia		−87	−96	−120		
Iberia		−88	−109	−122		
11. Ordnance Survey of Great Britain 1936	Airy	375	−111	431	573.604	0.11960 023
12. Ireland 1965	Mod. Airy	506	−122	611	796.811	0.11960 023
13. Merchich	Clarke 1880	31	146	47	−112.145	−0.54750 714
14. Adindan	Clarke 1880				−112.145	−0.54750 714
Ethiopia		−165	−11	206		
Sudan		−161	−14	205		

Table 2. Molodenskiy Transformation Constants to Convert From Local Datum to WGS 84 (page 1 of 3).

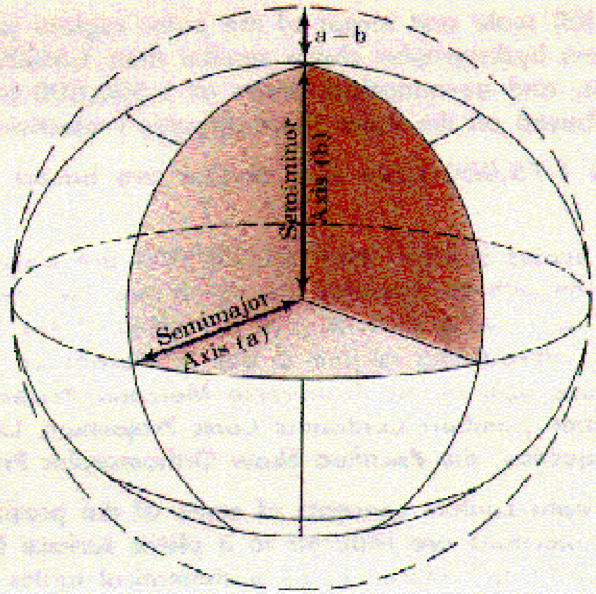
15. Liberia	Clarke 1880	−90	40	88	−112.145	−0.54750 714
16. Minna	Clarke 1880	−92	−93	122	−112.145	−0.54750 714
17. Arc 50	Clarke 1880				−112.145	−0.54750 714
Botswana		−138	−105	−289		
Kenya		−161	−7	−300		
Lesotho		−125	−108	−295		
Uganda		−158	−12	−299		
Zaire		−169	−19	−278		
Zambia		−147	−74	−283		
Zimbabwe		−142	−96	−293		
18. Tananarive Obsv. 1925	International	−189	−242	−91	−251	−0.14192 702
19. Tokyo	Bessel 1841	−128	481	664	739.845	0.10037 483
20. Hu-Tzu-Shan	International	−634	−549	−201	−251	−0.14192 702
21. Luzon	Clarke 1866	−133	−77	−51	−69.4	−0.37264 639
22. Kertau 1948	Mod. Everest	11	851	5	832.937	0.28361 368
23. Timbalai 1948	Everest	−689	691	−46	860.655	0.28361 368
24. Djakarta	Bessel 1841	−377	681	−50	739.845	0.10037 483
25. Bukit Rimpah	Bessel 1841	−384	664	−48	739.845	0.10037 483
26. Gunung Segara	Bessel 1841	−403	684	41	739.845	0.10037 483
27. Australian Geodetic 1966	Australian Nat.	−133	−48	148	−23	−0.00081 204
28. Geodetic Datum 1949	International	84	−22	209	−251	−0.14192 702
29. Guam 1963	Clarke 1866	−100	−248	259	−69.4	−0.37264 639
30. Local Astro	Transformations are not available for areas referenced to multiple astronomic stations. When a single astronomic station is used, a transformation may be possible, such as:					
Naparima Trinidad and Tobago	International	−2	374	172	−251	−0.14192 702

Table 2. Molodenskiy Transformation Constants to Convert From Local Datum to WGS 84 – continued.

31. Camp Area Astro	International	−104	−129	239	−251	−0.14192 702

Note: These shift constants are the best available at the time of publication.
The latest values may be obtained from DMA, ATTN: PR.

Table 2. Molodenskiy Transformation Constants to Convert From Local Datum to WGS 84 – continued.



ELLIPSOID	SEMI-MAJOR AXIS (a)	SEMI-MINOR AXIS (b)	1/f[1]
AIRY	6,377,563.396	6,356,256.910	299.32496 46
AUSTRALIAN NATIONAL OR SOUTH AMERICAN 1969	6,378,160	6,356,774.7192	298.25
BESSEL 1841	6,377,397.155	6,356,078.9629	299.15281 28
CLARKE 1866	6,378,206.4	6,356,583.8	294.97869 82
CLARKE 1880	6,378,249.145	6,356,514.8696	293.465
EVEREST	6,377,276.34518	6,356,075.41511	300.8017
GEODETIC REFERENCE SYSTEM 1980[2]	6,378,137	6,356,752.3141	298.25722 2101
INTERNATIONAL	6,378,388	6,356,911.9462	297
MODIFIED AIRY	6,377,340.189	6,356,034.446	299.32496 46
MODIFIED EVEREST[3]	6,377,304.063	6,356,103.039	300.8017
WORLD GEODETIC SYSTEM 1972	6,378,135	6,356,750.5	298.26
WORLD GEODETIC SYSTEM 1984	6,378,137	6,356,752.3142	298.25722 3563

[1] The flattening $f=(a-b)/a$. It is normally expressed by the reciprocal $1/f$.

[2] For cartographic purposes, the GRS 80 and WGS 84 ellipsoids are interchangeable.

[3] This ellipsoid has the same flattening as the Everest Ellipsoid, but a slightly larger axis (28 meters) because of the difference between foot-meter relationships used in Malaysia and the one used in India.

Figure 1. Defining parameters of ellipsoids.

2-5.2.2 Maps at 1:1,000,000 scale between 80° south and 84° north, some hydrographic charts, and aeronautical charts at 1:500,000 between 80° south and 80° north, are based on the Lambert Conformal Conic Projection.
2-5.2.3 Maps at 1:1,000,000 scale and larger of the polar regions (south of 80° south and north of 84° north), some hydrographic charts smaller than 1:50,000 and at latitude between 70° and the poles, and aeronautical charts at 1:500,000 north of 80° north or south of 80° south, are base, on the Polar Stereographic Projection.
2-5.2.4 Coastal charts at 1:75,000 scale and smaller are based on the Mercator Projection.
2-5.2.5 General maps at scales smaller than 1:1,000,000 are based on projections individually selected to conform with the intended use of the map. Because of their variety, complexity, and limited use, such projections are not described in this manual.
2-5.2.6 Maps produced by coproducing nations in non-U.S. areas of responsibility may be based on other projections such as the Transverse Mercator Projection, the Lambert Conical Orthomorphic Projection (Lambert Conformal Conic Projection), Laborde Projection, New Zealand Map Grid Projection, the Rectified Skew Orthomorphic Projection, etc.
2-5.3 The following paragraphs contain concepts of some of the prescribed projections; in practice, however, the projections are reduced to a plane surface by use of mathematical formulas. (See Chapter 1 for references to mathematical tables.) Figures 2, 3, 4, 5, and 6 are provided as an aid in the, understanding of these concepts.
2-5.4 The Mercator Projection is not normally used for military topographic maps; however, it is used extensively for naval ocean navigation and bathymetric charts. Its description also serves as a basis for understanding the Transverse Mercator Projection. The Mercator Projection can be visualized as an ellipsoid projected onto a cylinder with tangency established at the Eqaator and with the polar axis of the ellipsoid in coincidence with the cylinder axis as shown in figure 2. The origins of the projection lines vary and are about three-quarters of the way back along the diameters in the equatorial plane. When the cylinder is opened and flattened, a distortion appears in the polar regions, in as much as the line representing the Equator is the true distance and each parallel is represented by a line as long as the Equator. The poles are infinitely distant from the Equator and can not be shown on the projection. Distortion becomes more pronounced as the distance north and south of the Equator increases. For example, the map scale at 60° north and 60° south is approximately twice that at the Equator.
2-5.5 A Transverse Mercator Projection is a Mercator Projection where the cylinder has been rotated or transversed 90°. The ellipsoid and cylinder are thus tangent along a meridian. By projecting the surface of the ellipsoid onto the cylinder, as shown in figure 3, in the same manner as for the Mercator Projection, the Transverse Mercator Projection is developed on the surface of the cylinder, which is then opened and flattened.
2-5.5.1 Distortion - The east and west extremities appear distorted at the outer edges when projected onto a cylinder. The two shaded areas of figure 3 show the varying distortion of two equivalent geographic areas on the some projection. Note that both areas extend 15°in longitude within the 30° to 45° south latitude bond. The area bounded by the 30° and 45° east meridians is greatly magnified in comparison to the area bounded by the 90° and 105° east meridians. When a meridian is tangent to the cylinder of projection, there is no distortion along that meridian. Distances along the tangent meridians are true distances, and all distances within 3° of the meridians are relatively accurate. Therefore, to minimize distortion, the Transverse Mercator Projection, for military purposes, uses 60 longitudinal zones, each zone 6° wide. For example, a zone centered on 3° (central meridian) is bounded by the O° and 6° meridians, and a zone centered on 9° is bounded by the 6° and 12° meridians.

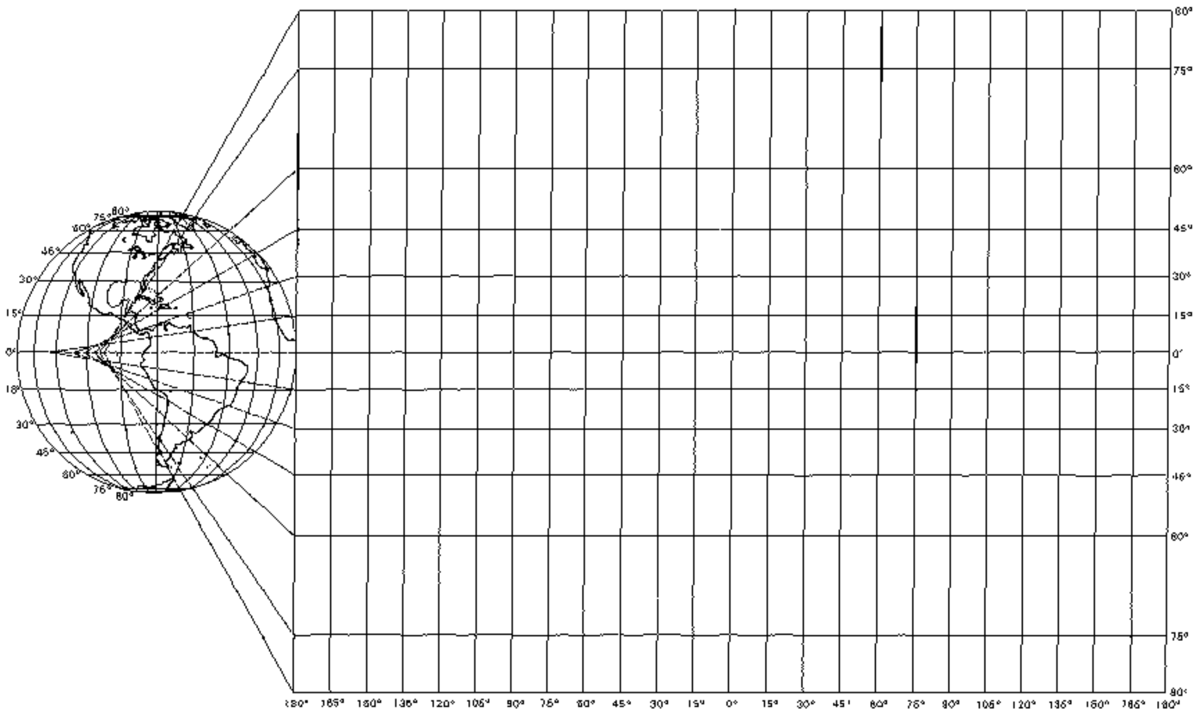


Figure 2. Mercator Projection.

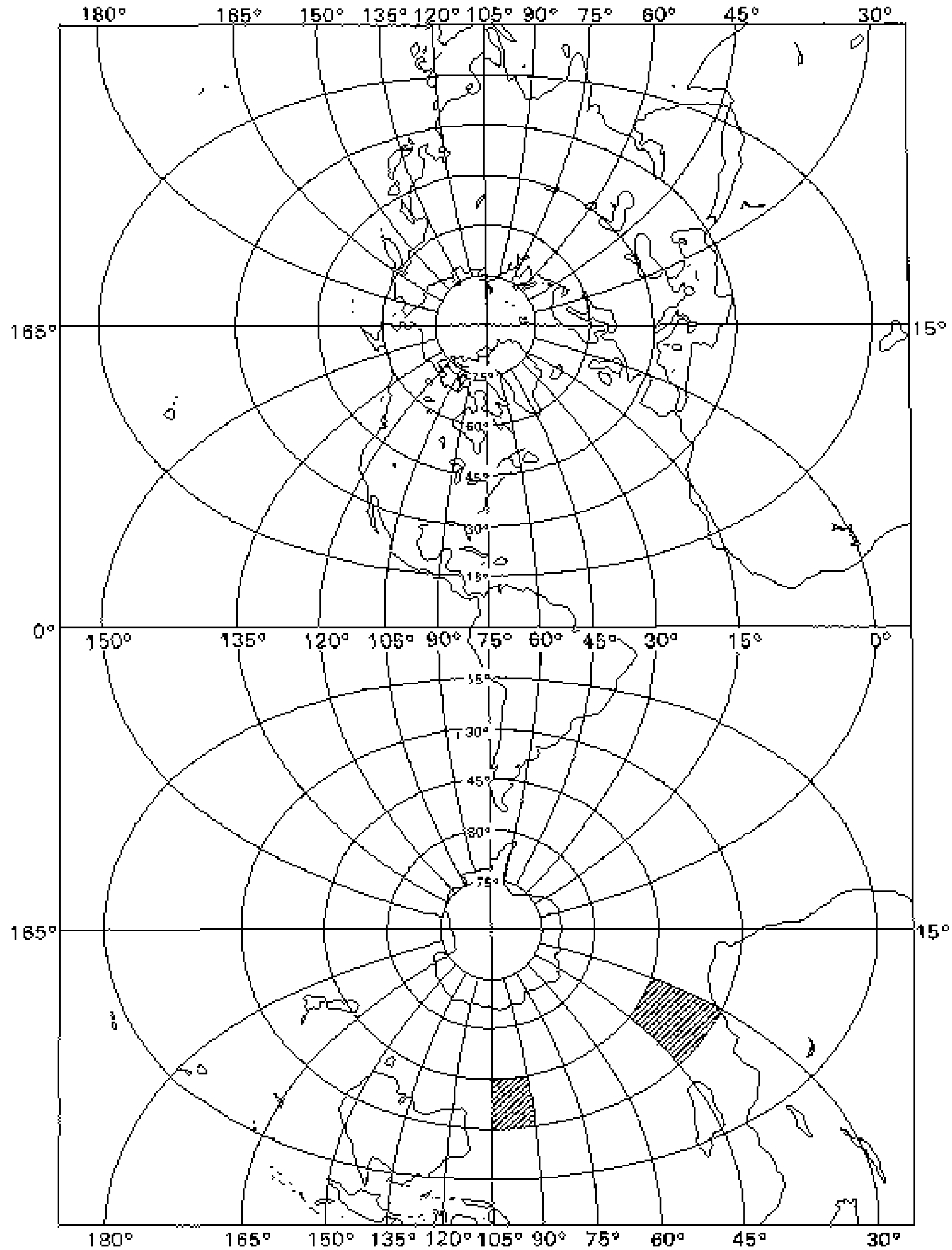


Figure 3. **Transverse Mercator Projection**

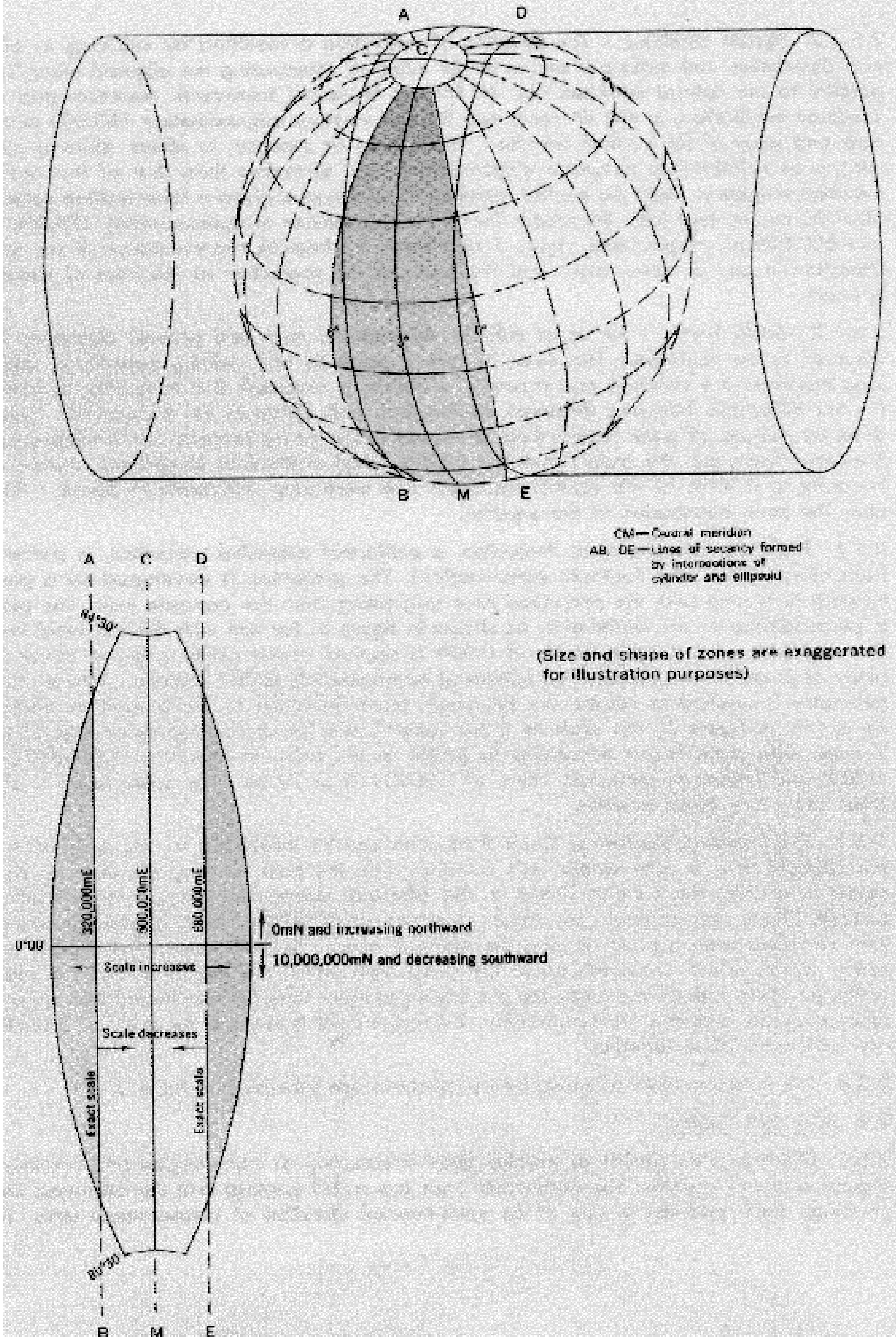


Figure 4. **Secant Condition of Transverse Mercator Projection; Typical 6-degree Projection Zone.**

2-5.5.2 Secant condition - The cylinder of projection is modified by reducing its elliptical dimensions and making it secant to the ellipsoid, intersecting the ellipsoid along lines parallel to the central meridian (fig. 4). For the Universal Transverse Mercator grid this condition establishes, in one 6° zone, two lines of secancy approximately 180,000 meters east and west of the central meridian. These lines of seconcy, in effect, allow a more congruous relationship between ellipsoid and map distances than that of the central meridian tangency. Since the central meridian of all zones is given a false easting value of 500,000 meters east (mE), the secant lines have coordinates of approximately 320,000 mE and 680,000 mE respectively. Figure 4 also gives a schematic representation of the scale distortion in any 6° zone. Note that the scale of the projection at the lines of secancy is exact.

2-5.5.3 Scale factor - For Most military operations, map and ground distances are assumed to be equivalent. However, in certain geodetic and artillery operations, where long distances are involved and accuracy of results is essential, it is necessary to correct for the difference between distances on the map and distances on the ground. This is done by the use of scale factors from prepared tables or by formula. For the Transverse Mercator Projection, the scale factor is 1.00000 (unity) at the lines of secancy, decreasing inwardly to 0.9996 at the central meridian, and increasing outwardly to about 1.0010 near the zone boundaries at The equator.

2-5.6 The Polar Stereographic Projection, a conformal azimuthal projection, is similar in both the northern and southern polar regions. The projection is developed on a plane tangent at a pole with the projection lines originating from the opposite pole. The plane is perpendicular to the minor axis, as shown in figure 5. For use with the Universal Polar Stereographic grid, a scale factor of 0.994 is applied at the origin (pole) to lower the plane of projection to intersect the sphere at approximately 81°07' latitude. This arbitrary geometry is applied to reduce the maximum scale distortion of the tangent projection. As shown in figure 5, the scale is exact (unity scale factor) at approximately 81'07' latitude. The scale factor decreases to 0.994 at the pole, increases to 1.0016076 at 80°00' and attains its maximum value of 1.0023916 at 79°30'. The scale factor is constant along any given parallel.

2-5.7 The Lambert Conformal Conic Projection can be visualized as the projection of the ellipsoid onto a cone whose axis coincides with the polar axis of the ellipsoid as in figure 6. Usually, the cone is secant to the ellipsoid, intersecting along two parallels of latitude. These two parallels are called standard parallels. Meridians appear as straight lines radiating from a point beyond the mapped areas. Parallels appear as arcs of concentric circles which are centered at the point from which the meridians radiate. None of the parallels appear in exactly the projected positions; they are mathematically adjusted to produce the property of conformality. This adjustment is slight if the standard parallels are sufficiently close together.

2-5.8 The characteristics of prescribed projections are tabulated in table 3.

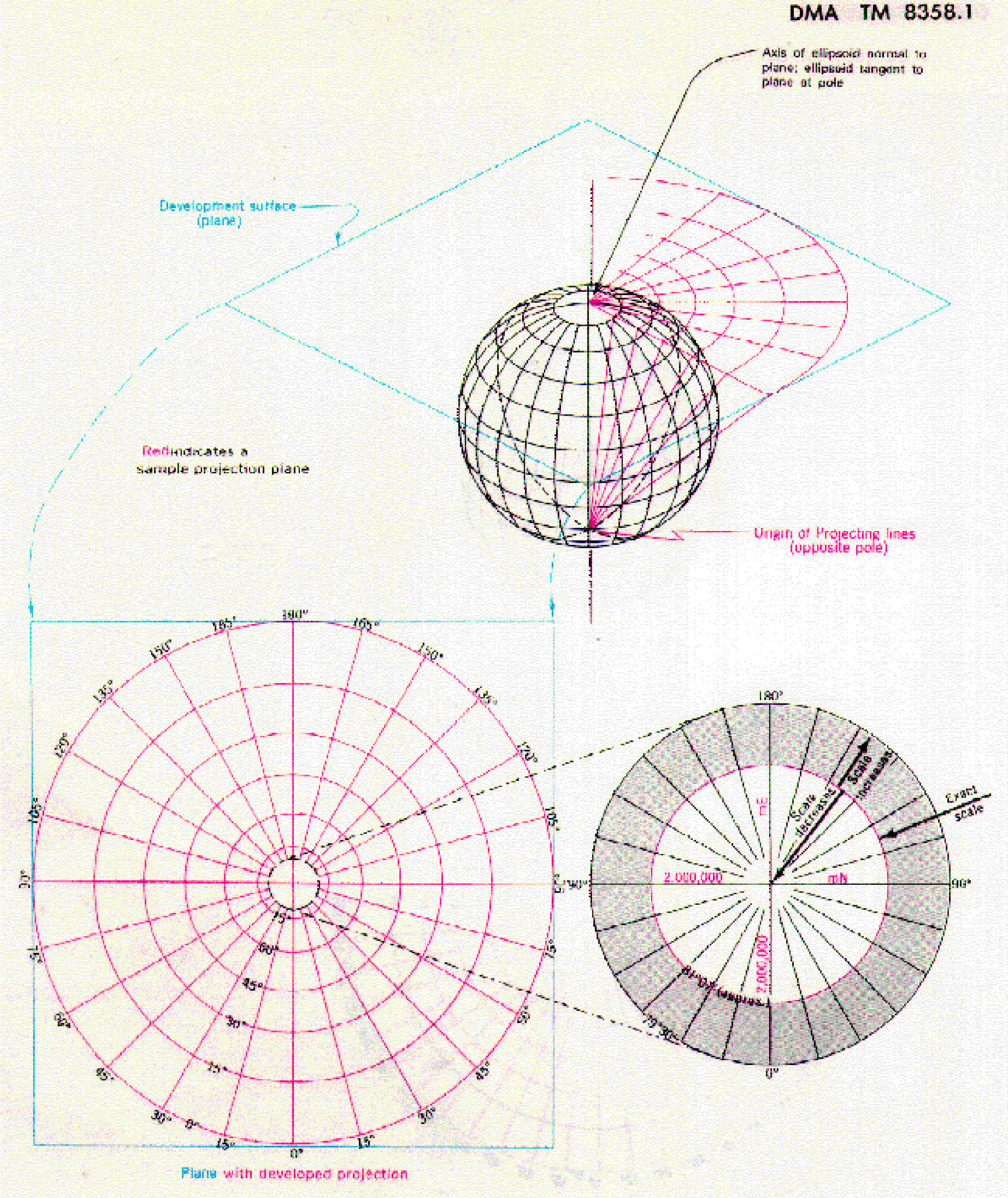
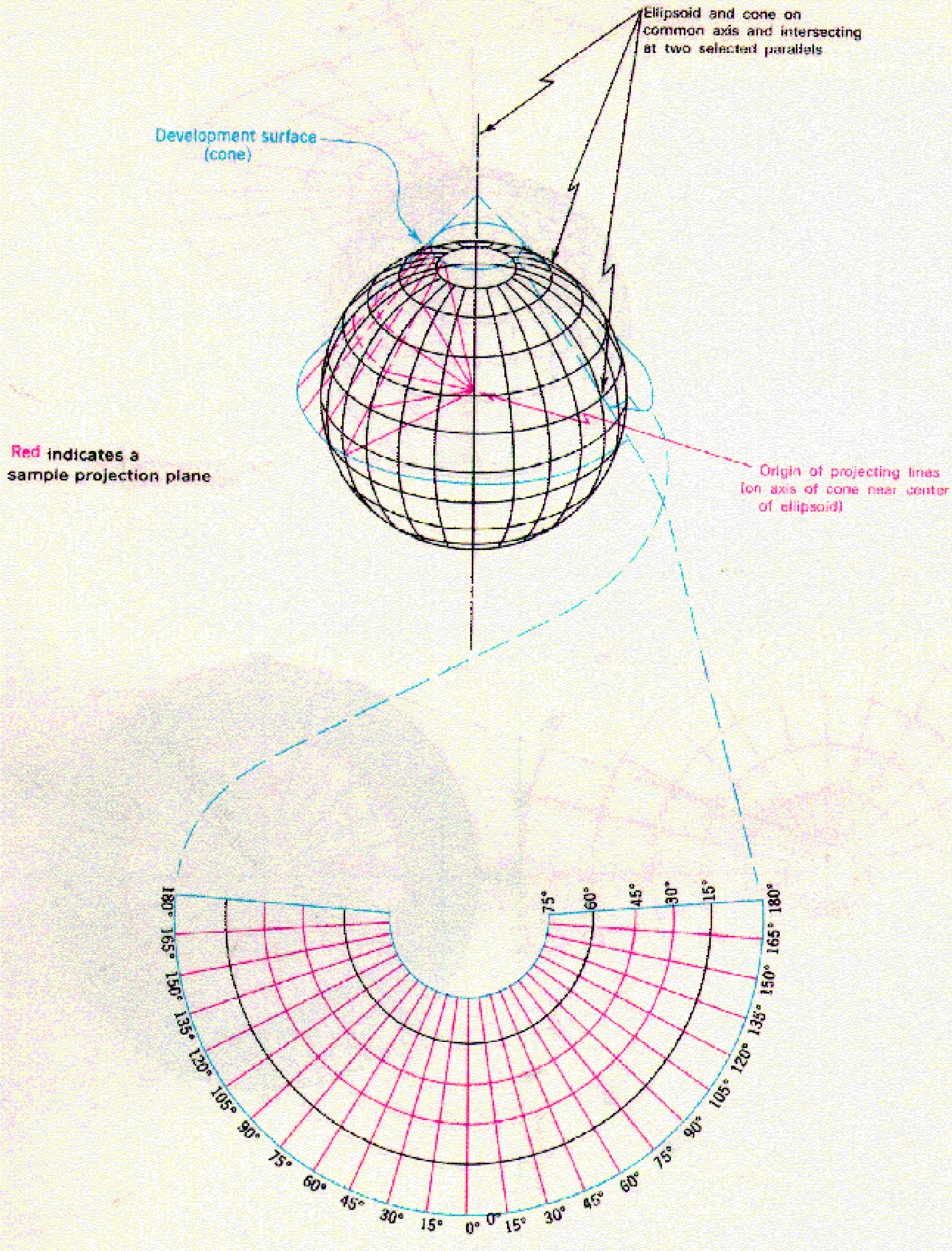


Figure 5. Polar Stereographic Projection



Flattened cone with developed projection

Figure 6. Lambert Conformal Conic Projection

CHARACTERISTICS	TRANSVERSE MERCATOR	POLAR STEREOGRAPHIC	LAMBERT CONFORMAL CONIC	MERCATOR
Origin of Projection Lines	a point on the diameter varying with the latitude, between the center and the opposite side	opposite pole	axis of cone near center of ellipsoid	a point on the diameter varying with the latitude, between the center and the opposite side
Development Surface	cylinder	plane	cone	cylinder
Tangency	central meridian	pole	central parallel	equator
Secancy	two eastings equidistant from the central meridian	concentric circle of unity scale factor	two standard parallels of unity scale factor	two standard parallels equidistant from the equator
Parallels	equator is a straight line; all others are curves concave toward the nearest pole	concentric circles unequally spaced	arcs of concentric circles whose spacing increases away from the central parallel	unequally spaced straight lines, closest near the equator
Meridians	central meridian is a straight line; all others are curved lines, concave toward the central meridian	straight lines radiating from the pole	straight lines converging on the projected polar axis	equally spaced straight lines
Scale Distortion	tangent – increases away from central meridian; secant – increases outward from secancy, decreases toward central meridian (see figure 4)	tangent – increases away from pole; secant – increases toward equator, decreases toward pole (see figure 5)	increases outward from standard parallel(s); decreases between standard parallels	tangent – increases away from the equator; secant – increases outward from secancy, decreases toward equator
Rhumb Line	curved line	curved line	curved line	straight line
Great Circle	curved line except central meridian and equator	straight line when through pole, all others are curved	approximate a straight line when between standard parallels	curve line
Use	topographic – 1:500,000 and larger hydrographic – 1:50,000 and larger aeronautical – 1:250,000	topographic, hydrographic aeronautical	topographic – 1:1,000,000 and smaller aeronautical – 1:500,000 and smaller	hydrographic

Table 3. Characteristics of projections.

2-6 MILITARY GRIDS

2-6.1 Military grids consist of parallel lines intersecting at right angles and forming a regular series of squares. The north-south lines are called eastings and the east-west lines northings. Each grid line is one of an even-interval selection of measurement units. The interval is selected in accordance with the map scale. The unit intervals shown on military map scales are:

MAP SCALES	UNIT INTERVALS
1:12,500	1,000
1:25,000	1,000
1:50,000	1,000
1:100,000	1,000 or 10,000
1:250,000	10,000
1:500,000	10,000
1:1,000,000	
100,000 with ticks at 10,000	

Table 4. Grid Unit Intervals for Various Scale Topographic Maps.

2-6.2 The grids preferred for military maps are:
2-6.2.1 Universal Transverse Mercator (UTM) grid for areas between 80° south and 84° north.
2-6.2.2 Universal Polar Stereographic (UPS) grid for the polar regions south of 80° south and north of 84° north. 2-6.2.3 Other grids for certain parts of the world as shown in Appendix D. These grids are being progressively replaced by the UTM grid, with the intent to eventually cover all military mapping of the world with a universal metric grid system.
2-6.2.4 Area of application for the various other grids are given in Appendix D. A general description of the grids and numbering systems is given in Chapter 4.

2-6.3 Specifications for the Universal Grid Systems follow:
2-6.3.1 Universal Transverse Mercator (UTM) Grid.
Projection: Transverse Mercator (Gauss-Kruger type) in zones 6° wide.

```
Ellipsoid:

  International
  Bessel 1841
  World Geodetic System 1984
  Geodetic Reference System (GRS 1980)
```

Longitude of Origin: Central meridian (CM) of each projection zone (3°, 9°, 15°, 21°, 27°, 33°, 39°, 45°, 51°, 57°, 63°, 69°, 75°, 81°, 87°, 93°, 99°, 105°, 111°, 117°, 123°, 129°, 135°, 141°, 147°, 153°, 159°, 165°, 171°, 177°, E and W).
Latitude of Origin: O° (the Equator).
Unit: Meter.
False Northing: 0 meters at the Equator for the Northern Hemisphere; 10,000,000 meters at the Equator for the Southern Hemisphere.
False Easting: 500,000 meters at the CM of each zone.
Scale Factor at the Central Meridian: 0.9996.
Grid Zone Designations: See Chapter 3 and Appendix B.
Latitude Limits of System: From 80°S to 84°N.
Limits of Projection Zones: The zones are bounded by meridians, the longitudes of which are multiples of 6° east and west of the prime meridian.
Overlap: On large-scale maps and trig lists, the data for each zone, datum, or ellipsoid overlaps the adjacent zone, datum, or ellipsoid a minimum of 40 kilometers. The UTM grid extends to 80°30'S and 84°30'N, providing a 30-minute overlap with the UPS grid.
2-6.3.2 Universal Polar Stereographic (UPS) Grid.
Projection: Polar Stereographic.
Ellipsoid: World Geodetic System 1984
Longitude of Origin: O° and 180°E-W.
Latitude of Origin: 90°N and 90°S.
Unit: Meter.
False Northing: 2,000,000 meters.
False Easting: 2,000,000 meters.
Scale Factor at the Origin: 0.994.
Grid Zone Designations: See Chapter 3 and Appendix B.

```
Limits of System:
     North Zone: Polar area north of 84°N.
     South Zone: Polar area south of 8O°S.
```

Overlap: The UPS grid extends to 83°30'N and 79°30'S, providing a 30-minute overlap with the UTM grid.
2-6.4 Formulas for constructing UTM and UPS grids are contained in DMA TM 8358.2.

2-7 TRANSFORMING COORDINATES FROM ONE GRID SYSTEM TO ANOTHER GRID SYSTEM.

Coordinates may be transformed from one grid system to another grid system, for instance, between a Lambert grid and a UTM grid or between different grid zones. The preferred procedure is to transform the grid coordinates from the first grid system to geographic positions. Then transform the geographic positions to grid coordinates of the second grid system. Note: This procedure does not change the datum. See paragraph 2-3 for the procedure to use when changing from one datum to another datum.

CHAPTER 3 THE U.S. MILITARY GRID REFERENCE SYSTEM (MGRS)

3-1 GENERAL DESCRIPTION

3-1.1 The U.S. Military Grid Reference System (MGRS) is designed for use with the UTM and UPS grids.
3-1.2 For convenience, the world is generally divided into 6° by 8° geographic areas, each of which is given a unique identification, called the Grid Zone Designation (fig. 7). These areas are covered by a pattern of 100,000-meter squares. Each square is identified by two letters called tie 100,000-meter square identification. This identification is unique within the area covered by the Grid Zone Designation. Exceptions to this general rule have been made in the post to preserve the 100,000-meter identifications on mapping that already exists. Appendix B shows the method for finding the 100,000-meter square identifications.
3-1.3 A reference keyed to a gridded map of any scale is made by giving the 100,000- meter square identification together with the numerical location. Numerical references within the 100,000-mater square are given to the desired accuracy in terms of the easting (E) and northing (N) grid coordinates for the point. The Grid Zone Designation usually is prefixed to the identification when references are made in more than one grid zone designation area.

3-2 THE GRID NORTH DESIGNATION.

3.2.1 An MGRS position location uses the standard military practice of reading "right (easting) and up (northing)". In each portion of a military grid reference (grid zone designation, 100,000-meter square identification, and grid coordinates), the first part provides the easting component and the second part provides the northing component.
3.2.2 The MGRS is on alphanumeric version of a numerical UTM or UPS grid coordinate.
3-2.2.1 For that portion of the world where the UTM grid is specified (80° south to 84° north), the UTM grid zone number is the first element of a Military Grid reference. This number sets the zone longitude limits. Zone 32 has been widened to 9° (at the expense of zone 31) between latitudes 56° and 64° to accommodate southwest Norway. Similarly, between 72° and 84°, zones 33 and 35 have been widened to 12° to accommodate Svalbard. To compensate for these 12° wide zones, zones 31 and 37 are widened to 9° and zones 32, 34, and 36 are eliminated.
3-2.2.2 The next element is a letter which designates a latitude bond. Beginning at 80° south and proceeding northward, twenty bands are lettered C through X, omitting I and O. The bands are all 8° wide except for bond X which Is 12° wide. Thus, in the UTM portion of the MGRS, the first three characters designate one of the 1197 areas with the dimensions as shown in Table 5.
3-2.2.3 In the Polar regions, there is no zone number. A single letter designates the semicircular area and hemisphere. Since the letters A, B, Y, and Z are used only in the Polar regions, their presence in an MGRS, with the omission of a zone number, designates that the coordinates are UPS.

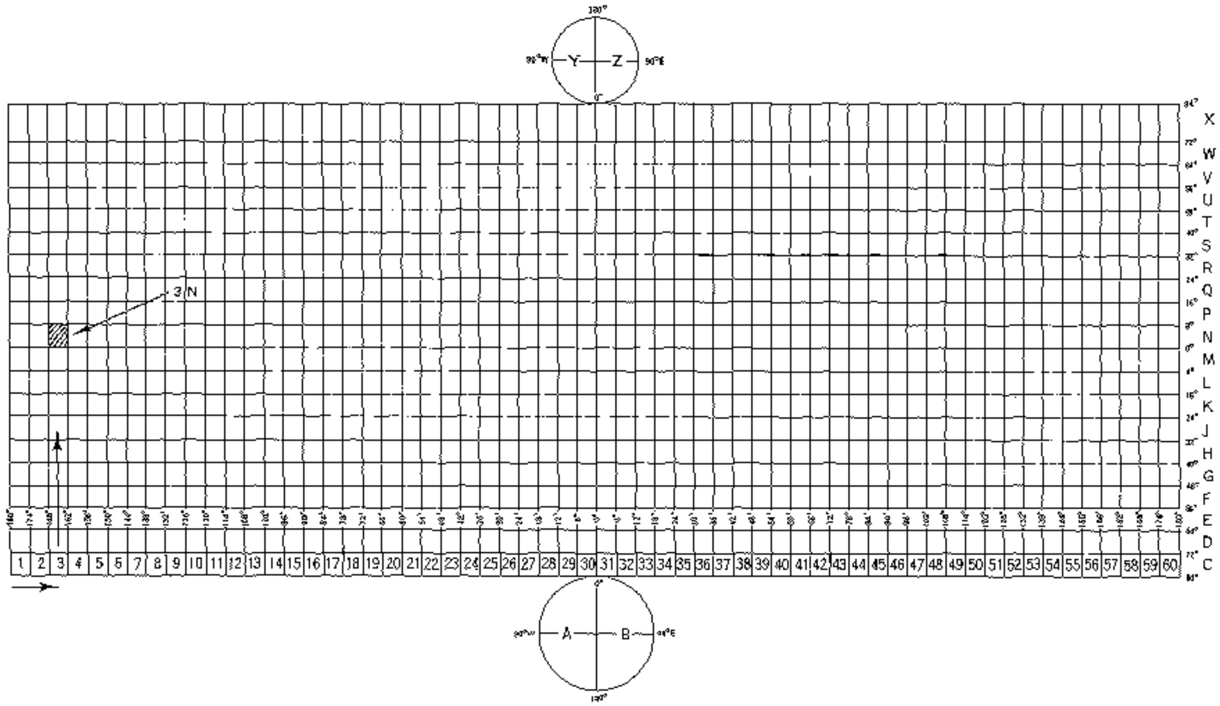


Figure 7. Grid Zone Designations of the Military Grid Reference System.

3-2.3 The grid zones are divided into a pattern of 100,000-meter grid squares forming a matrix of rows and columns. Each row and each column is sequentially lettered such that two letters provide, a unique identification, within approximately 9°, for each 100,000- meter grid square. Appendix B provides the location and identification of the grid zones and 100,000-meter grid squares.

Latitude	Longitude	Number
8°	6°	1138
8°	9°	1
8°	3°	1
12°	6°	53
12°	9°	2
12°	12°	2

Table 5. Dimensions of Grid Zone Designation Areas.

3-2.3.1 For many years efforts hove been made to reduce the complexity of grid reference systems by standardization to a single world-wide grid reference system. This effort is continuing and will generate additional changes to Appendixes B and D.
3-2.3.2 The remainder of this chapter describes the determination of the 100,000-meter square identification, and the military grid reference.

3-3 100,000-METER SQUARE IDENTIFICATION.

3-3.1 The 100,000-meter columns, including partial columns along zone, datum, and ellipsoid junctions, are lettered alphabetically, A through Z (with I and O omitted), north and south of the Equator, starting at the 180° meridian and proceeding easterly for 18°. The alphabetical sequence repeats at 18° intervals.
3-3.2 To prevent ambiguity of identifications along ellipsoid junctions changes in the order of the row letters are necessary. The row alphabet (second letter) is shifted ten letters. This decreased the maximum distance in which the 100,000-meter square identification is repeated.

3-3.3 The 100,000-meter row lettering is based on a 20-letter alphabetical sequence (A through V with I and O omitted). This alphabetical sequence is read from south to north, and repeated at 2,000,000-meter intervals from the Equator.
3-3.3.1 The row letters in each odd numbered 6° grid zone are read in an A through V sequence from south to north.
3-3.3.2 In each even-numbered 6° grid zone, the some lettering sequence is advanced five letters to F, continued sequentially through V and followed by A through V.
3-3.3.3 The advancement or staggering of row letters for the even-numbered zones lengthens the distance between 100,000-meter squares of the same identification.
3-3.4 Users are cautioned that deviations from the preceding rules were mode in the past. These deviations were an attempt to provide unique grid references within a complicated and disparate world-wide mapping system.
3-3.5 Determination of 100,000-meter grid square identification is further complicated by the use of different ellipsoids. Figure 8 shows the basic lettering system. Appendix B provides detailed guidance for finding the correct identification in each ellipsoid area.

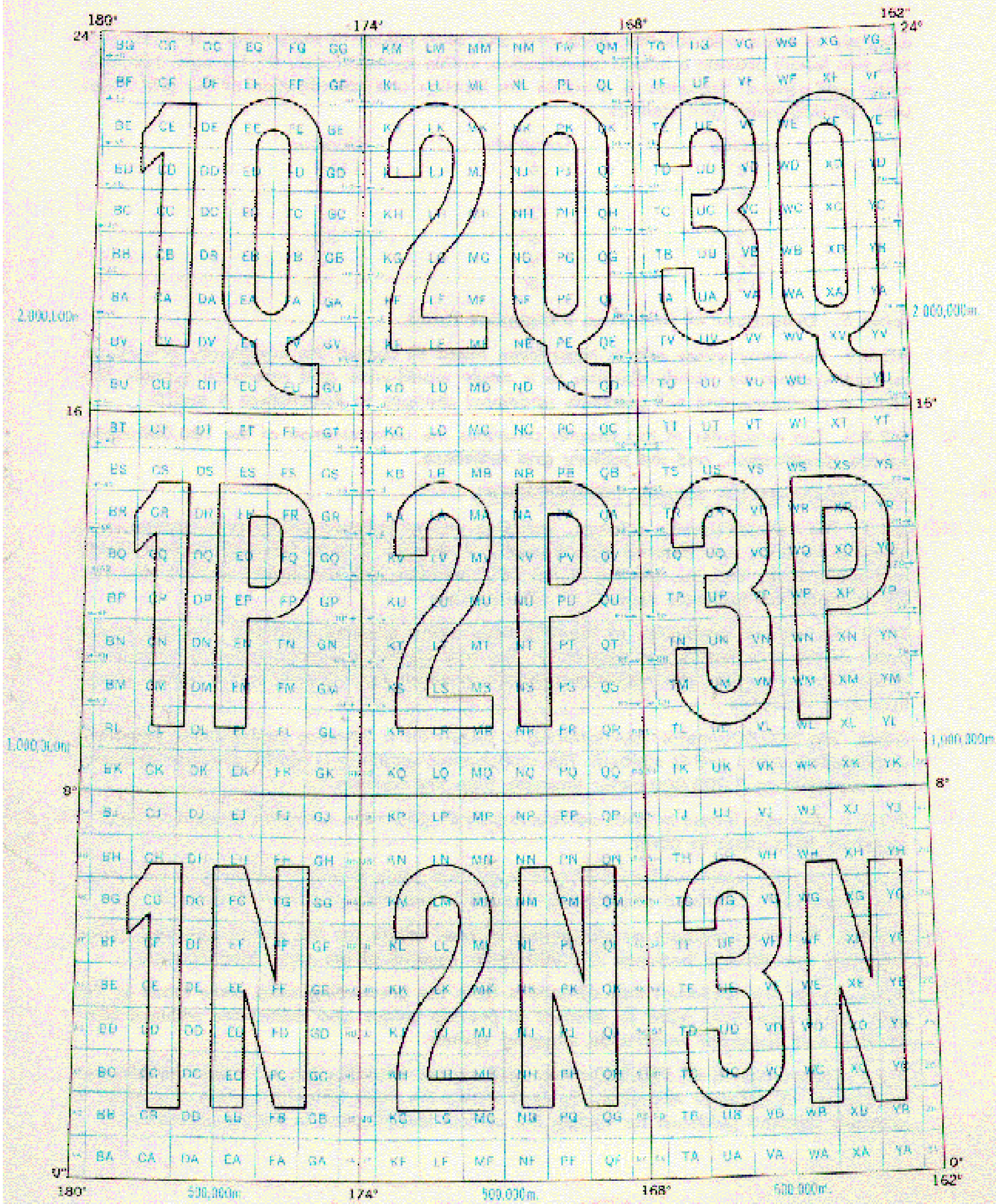


Figure 8. **Basic Plan of the 100,000-meter Square Identifications of the U.S. Military Grid Reference System, Between 84°N. and 80°S.**

3-4 THE MILITARY GRID REFERENCE.

3-4.1 The MGRS coordinate for a position consists of a group of letters and numbers which include the following elements:
3-4.1.1 The Grid Zone Designation.
3-4.1.2 The 100,000-meter square letter identification.
3-4.1.3 The grid coordinates (also referred to as rectangular coordinates); the numerical portion of the reference expressed to a desired refinement.
3-4.2 A reference is written as an entity without spaces, parentheses, dashes, or decimal points.

Examples

18S	(Locating a point within the Grid Zone Designation)
18SUU	(Locating a point within a 100,000-meter square)
18SUU80	(Locating a point within a 10,000-meter square)
18SUU8401	(Locating a point within a 1,000-meter square)
18SUU836014	(Locating a point within a 100-meter square)

3-4.3 To satisfy special needs, a reference can be given to a 10-meter square and a 1-meter square as:

18SUU83630143	(Locating a point within a 10-meter square)
18SUU8362601432	(Locating a point within a 1-meter square)

3-5 MGRS APPLICATION.

3-5.1 All elements of a grid reference need not be used. Their use depends upon the size of the area of Activities, the type of military operations, and the scale of the map to which the reference is keyed. The military area commander usually designates the elements of the grid references to be used. The following paragraphs provide guidance for the use of Grid Zone Designations and 100,000-meter square identifications.
3-5.1.1 For military operations spanning large geographical areas, the Grid Zone Designation is usually given (such as IBS). This designation will alleviate ambiguity between identical references that may occur when reporting to a station outside the area. The Grid Zone Designation is always used in giving references on 1:1,000,000 scale and 1:500,000 scale maps.
3-5.1.2 For operational areas of lesser extent, but exceeding 100,000 meters, the 100,000-meter square identification is used (such as UU80). The 100,000-meter square identification is uses in reporting references on the 1:250,000 and larger scale maps to avoid ambiguity between identical references which occur every 100,000 motors, and near grid zone junctions and ellipsoid junctions.

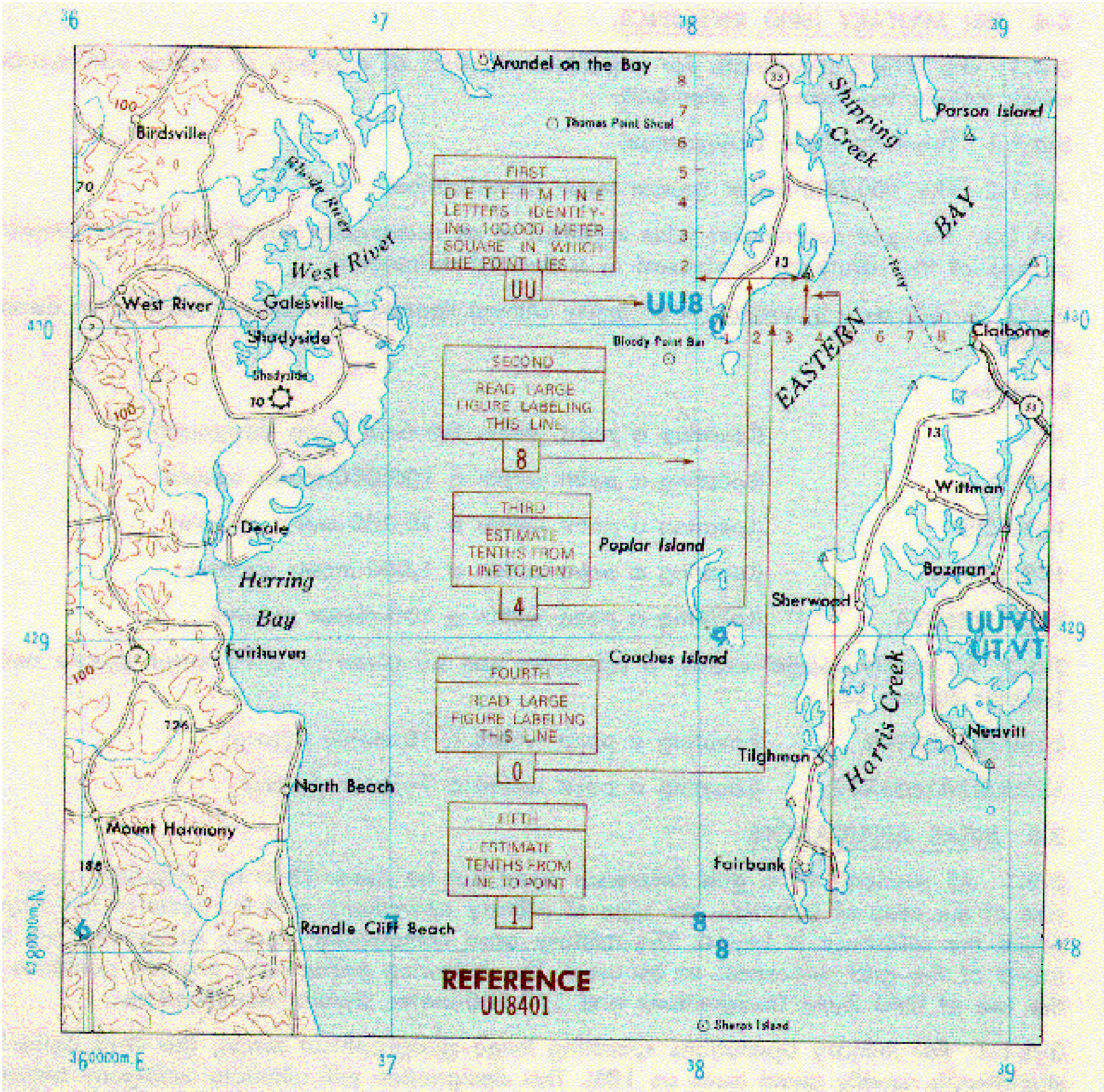


Figure 9. Method of Reading a U.S. Military Grid Reference from a 1:250,000 Scale Map

3-5.1.3 For small and localized operational areas, the Grid Zone Designations and 100,000-meter square identifications are not used, unless reporting falls within the parameters explained in preceding paragraphs. In the instance of local report only the numerical part of the grid reference is used (such as 836014). This condition applies to 1:100,000 scale maps and larger.

3-5.1.4 Topographic maps at scales 1:500,000 and larger provide a grid reference box with the elements and instructions for making a complete grid reference.

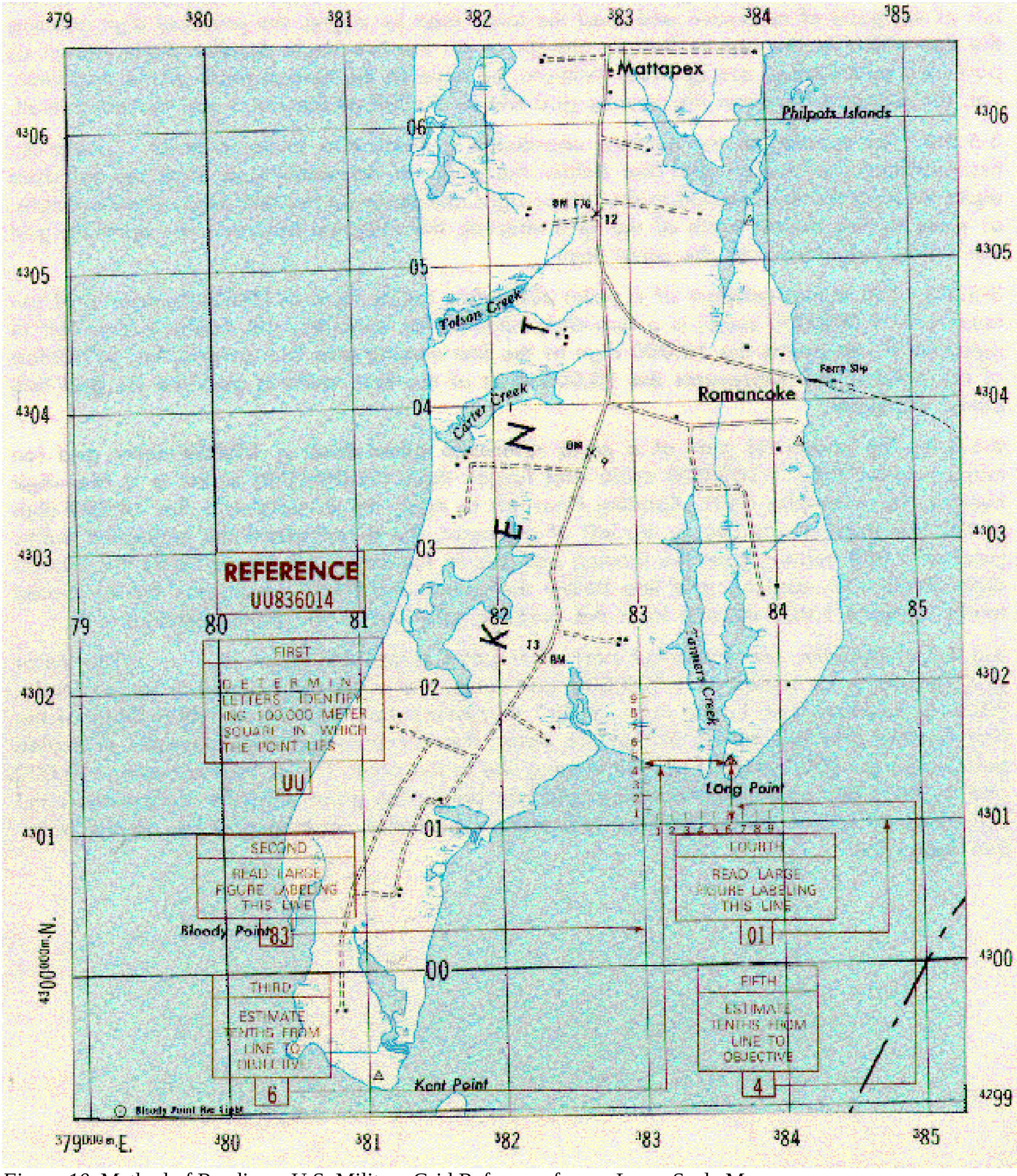


Figure 10. Method of Reading a U.S. Military Grid Reference from a Large Scale Map

3.5.2 The numerical part of a grid reference always contains an even number of digits. The first half of the total number of digits represents the easting, and second half the northing. The standard military practice of reading "right (easting) and up (northing)" is employed.

3-5.2.1 To read the easting coordinate, locate the first easting (vertical) grid line to the left of the point of reference and read the large digit (or digits), the principal digit labeling the line either in the top or bottom margin or on the line itself. Smaller digits shown as part of a grid number are ignored. Estimate, or scale to the closest tenth of the grid interval, the distance between the easting grid line to the left of the point and the point itself.

3-5.2.2 The reading of the northing coordinate is made in a similar manner. Locate the first northing (horizontal) grid line below the point of reference and read the principal digits labeling the line located in the left or right margin or on the line itself. Then estimate, or scale to the closest tenth of the grid interval, the distance between the northing grid line below the point and the point itself.

3-5.2.3 The numerical part of a point reference taken from a 100,000-meter grid (on maps of 1:1,000,000 scale) is a two-digit number; for example: 80. Reading from left to right, the 8 represents the 10,000 digit of the first easting grid line (or grid tick) to the left of the point; the 0 represents the 10,000 digit of the first northing grid line (or grid tick) below the point.

3-5.2.4 The numerical part of a point reference taken from a 10,000-meter grid (on maps smaller than 1:100,000 scale and larger than 1:1,000,000 scale) is a four-digit number; for example: 8401. Reading from left to right, the 8 represents the 10,000 digit of the first easting grid line to the left of the point, the 4 represents the estimated tenths (nearest 1,000 meters) from the easting grid line to the point, the 0 represents the 10,000 digit of the first northing grid line below the point, and the 1 represents the estimated tenths (nearest 1,000 meters) from the northing grid line to the point. See figure 9.

3-5.2.5 Normally, the numerical part of a point reference taken from a 1,000-meter grid (on maps at scales of 1:100,000 and larger) is a six-digit number; for example: 836014. Reading from left to right, the 83 represents the 10,000 and 1,000 digits of the first easting grid line to the left of the point, the 6 represents the estimated or scaled tenths (nearest 100 meters) from the easting line to the point, the 01 represents the 10,000 and 1,000 digits of the first northing grid line below the point, and the 4 represents the estimated or scaled tenths (nearest 100 meters) from the northing grid line to the point. See figure 10.

CHAPTER 4 THE NONSTANDARD GRID SYSTEMS IN CURRENT USE

CHAPTER 4 THE NONSTANDARD SYSTEMS IN CURRENT USE

4-1 NONSTANDARD GRIDS ON MAPS AND CHARTS.

4-1.1 Nonstandard Grids.

4-1.1.1 There is no regular or uniform global plan for the various grids which make up the nonstandard grid systems. Some were originally developed by the native country and later conveniently adopted by the British and U.S. with or without modifications. Others are of British or French origin. The systems were devised or adopted at different times and, except in certain geographic areas, do not have a direct relationship with one another. Primary considerations in the selection of a grid were the projection, ellipsoid, origin, false coordinates for the origin, and limits which would best suit the particular area. Consequently, various projections and ellipsoids have been employed. Nomenclature, sizes, predominant directions, and outlines of the grids vary considerably. This is demonstrated in Appendix D, which illustrates the layout of the nonstandard grids. This displays what is currently specified for new products and maintenance.

4-1.1.2 The nomenclature for the nonstandard grids includes the terms grid, zone, and belt to characterize the systems.

4-1.1.2.1 A grid covers a relatively small area. Its limits consist of combinations of meridians, parallels, loxodomes (rhumb lines), or grid lines. The origin of each grid is arbitrary. It is generally located approximately in the center of the grid and may bear no relation to the origins of other grids or to those of adjacent grids.

4-1.1.2.2 A zone usually is wide in longitude and comparatively narrow in latitude. Its limits, which are regular or in a few cases but irregular in most, consist of parallels and meridians. Each zone has its own origin which, with some few exceptions, falls within the limits of the zone. There is no relation between the origins of the zones, although, in a regional geographic area, those of adjacent zones may be on a common meridian or parallel.

4-1.1.2.3 A belt originally referred to a grid that was extensive in latitude, but narrow in longitude.

4-1.1.3 Each grid, zone, and belt has a name. Where groups of adjacent grids or zones cover a regional geographic area, the some name may be used for each; distinction is preserved by adding either a cardinal point or a number and a letter to the name.

4-1.1.4 The unit of measure is either meters or yards.

4-1.1.5 Normally, a British grid or zone is divided into 500,000-unit squares with each square identified by a letter of the alphabet. In a square composed of twenty-five 500,000- unit squares the letters are arranged alphabetically (the letter I is omitted) in a left to right - top to bottom fashion. Each 500,000-unit is similarly divided into twenty-five 100,000-unit squared, each of which is Identified by a letter following the some plan as for the 500,000-unit squares. The Normal Lettering Plan is illustrated in figure 11. This basic lettering plan is repeated for India Zone IIIA where it exceeds 2,500,000 yards in easting.

4-1.1.6 Among the British grids, deviations from the normal lettering system exist for the Irish Transverse Mercator Grid.

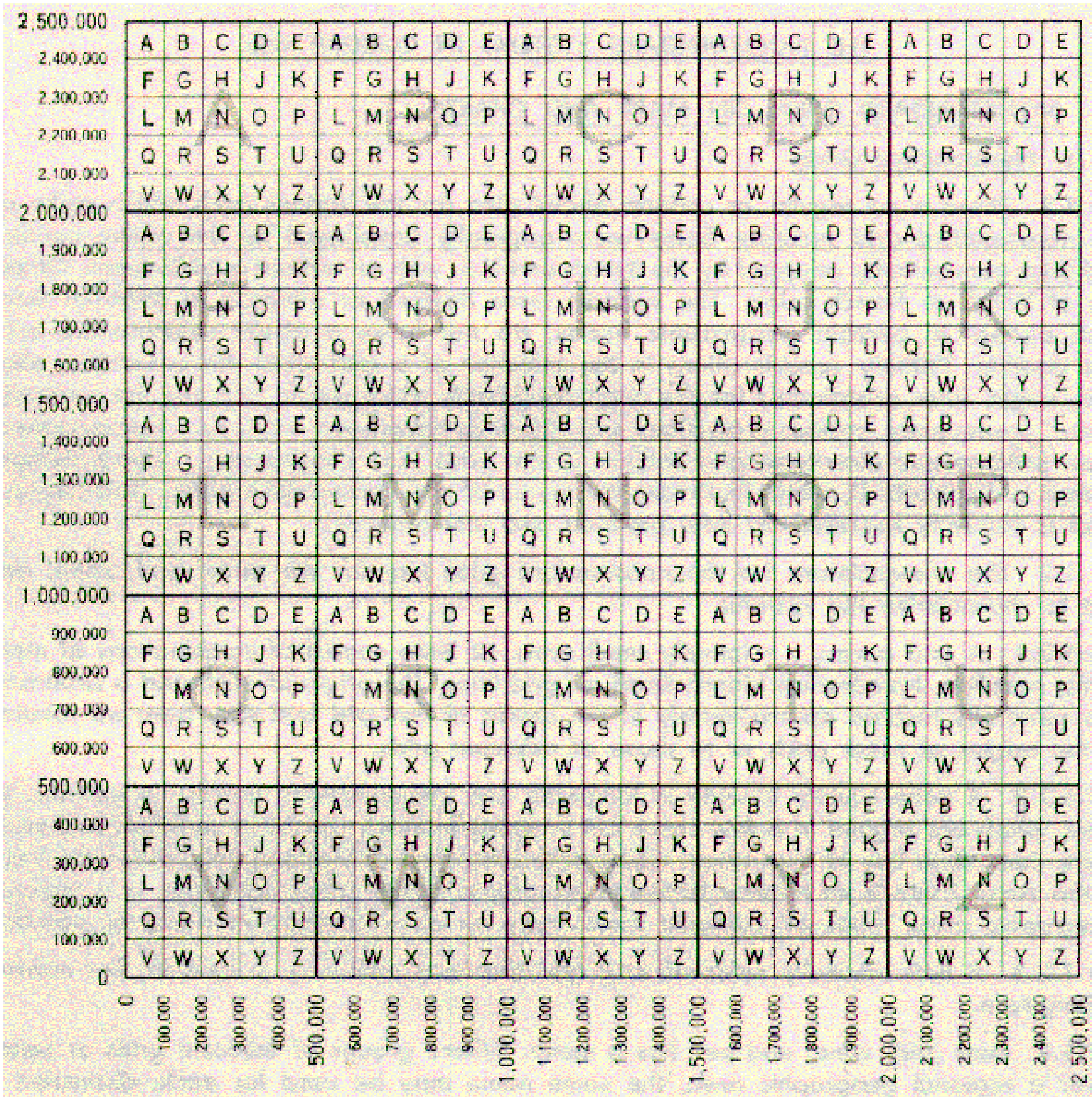


Figure 11. **Normal Lettering Plan of the 500,000- 100,000-unit squares of the British Grid System.**

4-1.1.7 No letters are used for the Ceylon Belt, New Zealand Map Grid, Nord Algerie Grid, Nord Maroc Grid, Nord Tunisie Grid, Sud Algerie Grid, Sud Maroc Grid, and Sud Tunisie Grid.
4-1.1.8 The secondary grids are constantly changing. Specifications for those grids currently in this category are given in table 6.

NAME	PROJECTION	ELLIPSIOD	ORIGIN LATITUDE	ORIGIN LONGITUDE	FALSE ORIGIN EASTING	FALSE ORIGIN NORTHING	SCALE FACTOR
British West Indies	TM	Clarke 1880	0°00′00.00″N	62°00′00 00″W	400,000.000m	0.	0 9995
Costa Rica							
Norte	Lambert	Clarke 1866	10°28′00.000″N	84°20′00 000″W	500,000.000m	271,820.522m	0.99995 696
Sud	Lambert	Clarke 1866	9°00′00.000″N	83°40′00 000″W	500,000 000m	327,987,436m	0 99995 696
Cuba							
Norte	Lambert	Clarke 1866	22°21′00 000″N	81°00′00 000″W	500,000.000m	280,296.016m	0.99993 602
Sud	Lambert	Clarke 1866	20°43′00 000″N	76°50′00 000″W	500,000.000m	229,126.939m	0.99994 848
Dominican Republic	Lambert	Clarke 1866	18°49′00.000″N	71°30′00 000″W	500,000 000m	277,063.657m	0 99991 102
Egypt	TM	International	0°00′00 000″N	25°30′00 000″E 28°30′00 000″E 31°30′00 000″E 34°30′00 000″E 37°30′00.000″E	300,000.000m	0.	0.99985
El Salvador	Lambert	Clarke 1866	13°47′00.000″N	89°00′00.000″W	500,000.000m	295,809.184m	0.99996 704
Guatemala							
Norte	Lambert	Clarke 1866	16°49′00 000″N	90°20′00.000″W	500,000,000m	292,209.579m	0.99992 226
Sud	Lambert	Clarke 1866	14°54′00.000″N	90°20′00 000″W	500,000.000m	325,992.681m	0.99989 906
Haiti	Lambert	Clarke 1866	18°49′00 000″N	71°30′00 000″W	500,000 000m	277,063.657m	0.99991 102
Honduras							
Norte	Lambert	Clarke 1866	15°30′00 000″N	86°10′00.000″W	500,000.000m	296,917.439m	0.99993 273
Sud	Lambert	Clarke 1866	13°47′00 000″N	87°10′00.000″W	500,000.000m	296,215.903m	0.99995 140
Levant	Lambert	Clarke 1880	34°39′00 000″N	37°21′00.000″E	300,000.000m	300,000.000m	0.99962 56
Nicaragua							
Norte	Lambert	Clarke 1866	13°52′00.000″N	85°30′00.000″W	500,000 000m	359,891.816m	0.99990 314
Sud	Lambert	Clarke 1866	11°44′00.000″N	85°30′00.000″W	500,000.000m	288,876.327m	0.99992 228
Northwest Africa	Lambert	Clarke 1880	34°00′00.000″N	0°00′00.000″E	1,000,000.000m	500,000.000m	0.99908
Palestine	TM	Clarke 1880[1]	31°44′02.749″N	35°12′43.490″E	170,251.555m[2]	126,867.909m[2]	1
Panama	Lambert	Clarke 1866	8°25′00.000″N	80°00′00 000″W	500,000.000m	294,865.303m	0.99989 909

[1] Clarke 1880 Ellipsoid for Palestine, $a = 6,378,300\ 79$ and $1/f = 293.46630\ 7656$.
[2] Add 1,000,000.00m to coordinate when corrdinate becomes negative.

Table 6. Specifications for secondary grids.

4-1.1.9 The Gauss-Kruger (GK) projection and grids are the basis for the UTM grid system. Within the scope of this manual, there are three GK systems that may be encountered even though the Defense Mapping Agency uses none of them. The Russian GK grid is discussed in Department of the Army Field Manual No. 34-85, Conversion of Warsaw pact Grids to UTM Grids. General specifications are as follows:
Projection: Transverse Mercator in zones 6" wide.

```
Ellipsoid:  Krassovskiy (a = 6,378,245 meters, 1/f = 298.3) (U.S.S.R., China to 1981).

            Geodetic Reference System of China 1980 (a = 6,378,140
meters,
            1/f = 298.257) (China from 1981).

            Bessel (Germany).
```

Longitude of Origin: Same as the UTM.
Latitude of Origin: Same as the UTM.
Unit: Meter.
False Easting: 500,000 meter at the CM of each zone. However, the zone number is prefixed to the false easting In most cases, i.e. the false easting for the GK zone 7 is 7,500,000 meters.
False Northing: Same as the UTM.
Scale Factor on Central Meridian: Unity (1).
Grid Zone Designations: The zones are numbered eastward from 1 to 60 starting at the Greenwich meridian rather than the 180' meridian. In other words, the UTM and GK zones differ by 30. Row letters are not used with the GK systems Limits of System: The limits north and south are not rigidly defined as with the UTM. However, the limits can be assumed to be similar to the UTM.
Overlap: Same as the UTM.,
4-1.1.10 The specifications for the nonstandard grids, including the various lettering systems, are shown later in this chapter.
4-1.2 Nonstandard Grids on Maps and Charts.

4-1.2.1 Maps at scales of 1:100,000 and larger are gridded at 1,000-unit intervals. Those at scales 1:250,000 and 1:500,000 are gridded at 10,000-unit intervals. Maps at scales 1:1,000,000 and smaller than 1:500,000 are gridded at 100,000-unit intervals intersected by ticks at 10,000-unit intervals.
4-1.2.2 Each grid line, except on maps at 1:1,000,000 scale, is labeled with its value in the margin and on the line itself. Maps at 1:1,000,000 scale are not labeled on the face of the map. In the margins, the grid values for each line are shown in two sizes of type. The larger digits - the principal digits - are the only digits to be used in determining a grid reference. On the face of the map, the grid lines are labeled with principal digits only. These grid-labeling practices are similar to those of the UTM and UPS grids.
4-1.2.2.1 The number of principal digits labeling the grid lines is dependent upon the particular grid and the interval of the grid lines.
4-1.2.2.2 With grids whose 100,000-unit squares ore identified by letters or numbers, the 10,000-unit or 100,000-unit interval grid lines are labeled with one principal digit only. This represents the 10,000 digit of the grid value. On maps in the same area whose grid lines appear at 1,000-unit intervals, the lines are labeled with two principal digits. These represent the 10,000 and 1,000 digits of the grid value.
4-1.2.2.3 Except the Ceylon Belt, the lines of grids whose 100,000-unit squares are not identified are labeled with two principal digits when the interval is 10,000 and with three principal digits when the interval is 1,000 units. At the 10,000-unit or 100,000- unit interval, the numbers represent the 100,000, 10,000, and 1,000 digits of the grid value.
4-1.2.2.4 With the Ceylon Belt, two principal digits are used, regardless of the interval of the grid lines. On maps gridded at 10,000- or 100,000-yard intervals, the numbers represent the 100,000 and 10,000 digits of the grid value. On maps gridded at 1,000- yard intervals, the numbers represent the 10,000 and 1,000 digits of the grid value.
4-1.2.3 The 100,000- and 500,000-unit square identifications are shown in several ways, depending upon the scale of the map.
4-1.2.3.1 On maps at British origin which are gridded at 10,000-unit intervals, a miniature representation of the 100,000-unit grid lines is printed in the index to adjoining sheets. Within each square is added the 100,000-unit square identification. If the 500,000-unit squares are identified, the identification is added in smaller type just before each 100,000- unit square identification such as sC. Similar identifications appear on the face of the map. These will be found either in the center or at the corners of each 100,000-unit square. Variations in these practices will often be encountered.
4-1.2.3.2 This same, plan is followed on maps of British origin which are gridded at 1,000-unit intervals, although in many cases it will be found that the identifications are omitted from the face of the map.
4-1.2.3.3 On U.S. maps containing nonstandard grids, a miniature representation of the sheet with 100,000-unit grid lines appears in the grid reference box which is part of the marginal data of the sheet. The appropriate 500,000- and 100,000-unit square identifications appear in each square of the miniature. These are written together, with the 500,000-unit square,identification appearing in smaller type, such as sC. Examples are illustrated in figure 27. Similar identifications appear on the face of maps gridded at 10,000-unit intervals.
4-1.3 <u>Referencing</u>
Two basic methods for giving grid references are used on maps with nonstandard grid reference systems. These are modified in some instances. The first method, referred to as the normal British grid reference system, is used with grids whose 100,000- unit squares are identified by letters. The second method, referred to as the abnormal grid reference system, is used with grids whose 100,000-unit squares are not identified.
4-1.4 <u>The Normal British Grid Reference System.</u>
4-1.4.1 The instructions contained in this section apply only to those grids which adhere to the normal lettering plan.
4-1.4.2 The normal method for giving a reference based on a British grid is similar to that used for the U,S. Military Grid Reference System. See Figures 10 and 11. A reference consists of a group of letters and numbers which indicate (1) the 500,000-unit square identification, (2) the 100,000-unit square identification, and (3) the grid coordinates - the numerical portion of the reference - expressed to a prescribed refinement. It is desirable to leave a space between letters and numbers.

Examples:

NT 65	(Locating a point within a 10,000-unit square)
NT 6354	(Locating a point within a 1,000-unit square)

NT 632543 (Locating a point within a 100-unit square)

4-1.4.3 The use of the letters of the 500,000- and 100,000-unit square identifications depends on the size of the area of operations. The above examples of reporting are desirable when reporting between 500,000-unit squares so that ambiguity in letter identifications may be avoided. However, when all reporting is within a 500,000-unit square, the 500,000-unit square identification letter may be dropped, and the 100,000-unit square identification is retained to avoid ambiguity in numerical coordinates. When the area of operations is completely localized within a 100,000-unit square, both the 500,000- and 100,000-unit square identifications may be dropped.

4-1.5 Exceptions to the Normal British Grid Reference System.

4-1.5.1 The letter I is used as the 500,000-meter square letter with the Irish Transverse Mercator.

4-1.5.2 No 500,000- and 100,000-meter square letters are used with the New Zealand Map Grid. To avoid ambiguity, references are prefixed with the sheet number. A space separates the sheet number from the numerical reference.

Examples:

Z15 894623 (Locating a point within a 1,000-meter square at 1:50,000 scale)

Sht 5 989362 (Locating a point within a 10,000-meter square at 1:250,000 scale)

4-1.6 The Abnormal Grid Reference System.

4-1.6.1 The abnormal grid reference system is used when 100,000-unit squares are not identified, as with the Madagascar grid and the Lambert Grids of northwestern Africa. The reference usually is expressed in terms of grid coordinates only and is determined in the same manner as that used with the normal British grid reference system. The number of digits in the reference depends upon the grid interval and the grid itself.

4-1.6.2 Except for the Ceylon Belt, an abnormal reference taken from a map gridded at 100,000-meter intervals consists of four digits; at 10,000 meters, six digits; and for 1,000-meter intervals, eight digits.

Examples:

8645 (Locating a point within a 10,000-meter square)

863454 (Locating a point within a 1,000-meter square)

86324543 (Locating a point within a 100-meter square)

4-1.6.3 References based on the Ceylon Belt use four digits on maps gridded at 100,000- yard intervals and six digits for all other grid intervals.

```
Examples:

     Reference from map gridded at 100,000-yard intervals.
     3524 (Locating a point within a 10,000-yard square)

     Reference from map gridded at 10,000-yard intervals.
     347241 (Locating a point within a 1,000-yard square)

     Reference from map gridded at 1,000-yard intervals.
     472413 (Locating C, point within a 100-yard square)
```

4-1.6.3.1 The Ceylon Belt grid reference system has a distinct disadvantage. Ambiguity between references is possible when six-digit reporting covers an area exceeding 100,000- yards square.

4-1.6.3.2 No official method is provided for preserving a distinction between the references. In practice, various devices have been used, such as prefixing the reference with the scale, name, or number of the map from which the reference was taken.

4-1.6.3.3 On maps prepared by the United States, the grid reference box will contain instructions for preserving distinctions. Normally, this will require prefixing the numerical reference with the sheet number of the map from which the reference was taken.

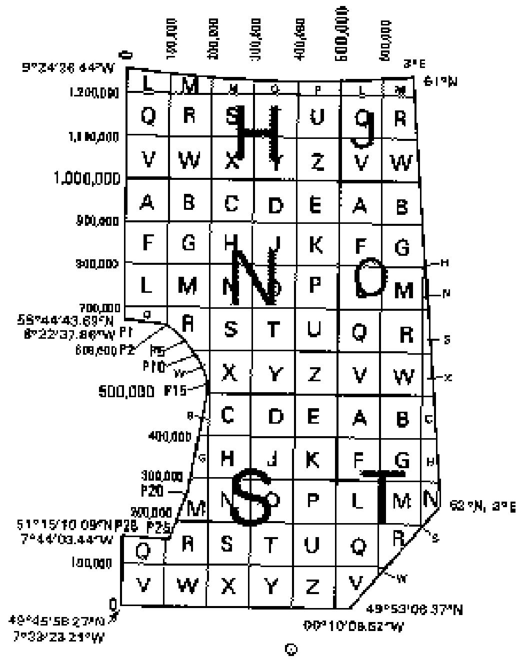
4-1.7 Unique Reporting.

Nonstandard reference systems, unlike the U.S. Military Grid Reference System, make no provisions for worldwide reporting. It may be necessary to identify the general areas in terms of geographic coordinates before giving the grid references for the separate general areas.

4-2 DIAGRAMS OF NONSTANDARD GRIDS.

The following pages show the diagrams and specifications of nonstandard grids used as the primary or secondary grid on maps produced by DMA:

BRITISH NATIONAL GRID



PROJECTION: Transverse Mercator
ELLIPSOID: Airy
UNIT: Meter
ORIGIN: 49°N., 2°W.
FALSE COORDINATES OF ORIGIN: 400,000 meters E.; -100,000 meters N.
SCALE FACTOR: 0.99960 12717
INCIDENCE OF GRID LETTERS: The 500,000-meter square letter S and the 100,000-meter square letter V are both north and east of the false origin.
GRID TABLES: *Projection Tables for the Transverse Mercator Projection of Great Britain.*
GRID "COLOR": Black
REFERENCING FOR 1,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-METER GRID (2-digit numerical reference):
Principal digits: (1); 10,000

See next page for junction with Irish TM Grid

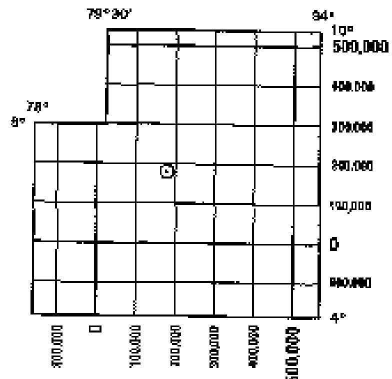
The junction with the Irish Transverse Mercator Grid is as follows:

POINT	LATITUDE	LONGITUDE
P1	55°44'43.69"N	8°22'37.86"W
P2	55°44'25.8"N	6°49'55.3"W
P3	55°38'53.1"N	6°35'11.6"W
P4	55°33'22.1"N	6°24'54.2"W
P5	55°27'50.4"N	6°14'47.7"W
P6	55°22'18.3"N	6°05'10.3"W
P7	55°16'45.8"N	5°55'55.8"W
P8	55°11'12.9"N	5°46'58.8"W
P9	55°05'39.4"N	5°38'05.8"W
P10	55°00'08.4"N	5°31'48.4"W
P11	54°54'37.4"N	5°25'49.5"W
P12	54°49'08.0"N	5°21'16.2"W
P13	54°38'10.5"N	5°13'31.2"W
P14	54°30'29.9"N	5°11'00.3"W
P15	54°21'58.8"N	5°12'44.6"W
P16	54°11'14.6"N	5°14'50.9"W
P17	53°55'09.1"N	5°18'45.9"W
P18	53°28'18.0"N	5°23'54.2"W
P19	53°01'26.5"N	5°28'55.6"W
P20	52°34'34.6"N	5°33'51.4"W
P21	52°19'50.3"N	5°36'29.8"W
P22	52°07'47.3"N	5°42'50.5"W
P23	51°41'04.5"N	5°56'41.0"W
P24	51°14'54.6"N	6°11'08.5"W
P25	51°14'21.1"N	6°11'45.0"W
P26	51°15'10.09"N	7°44'03.44"W
Dover Straits	52°00'00.00"N	3°00'00.00"E
Loxodrome	49°53'06.37"N	0°10'06.52"W

The geographic values for these points are the same in the Ireland 1965 and the Ordnance Survey of Great Britian 1936 datums.

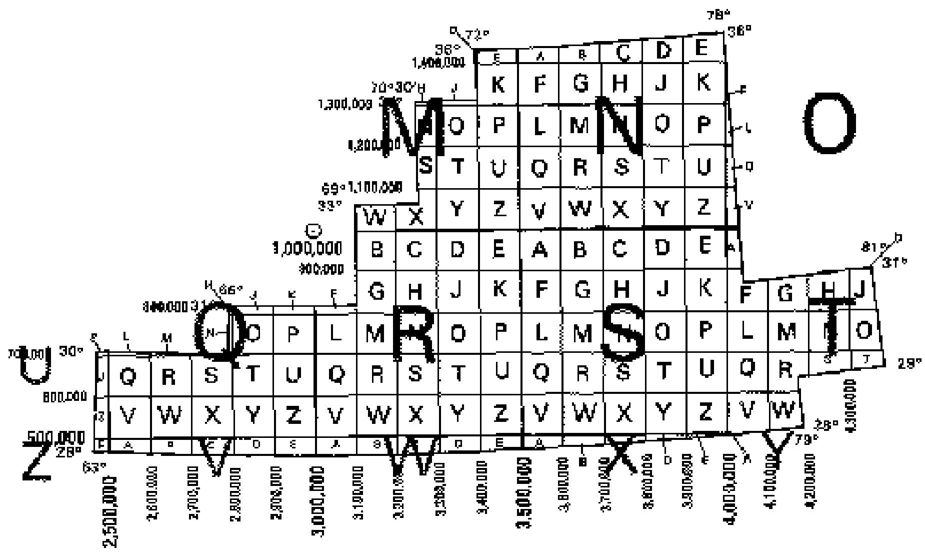
Page 4-9 Junction with Irish Transverse Mercator Grid

CEYLON BELT



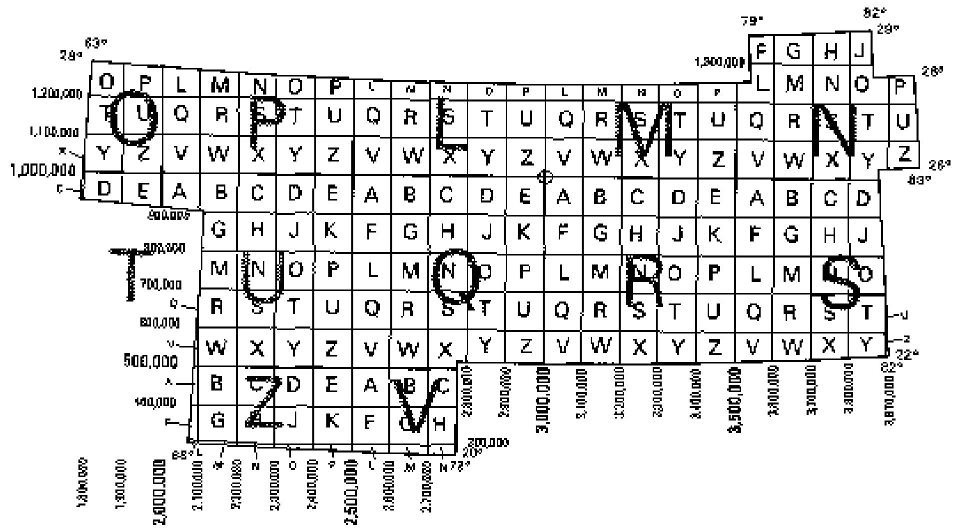
PROJECTION: Transverse Mercator
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards, 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 7°00′01.729″N., 80°46′18.160″E.
FALSE COORDINATES OF ORIGIN: 176,000 yards E., 176,000 yards N.[south and west of the false origin (0 yards E. and 0 yards N. grid lines) add 1,000,000 yards to the easting and northing.]
SCALE FACTOR: Unity
INCIDENCE OF GRID LETTERS: No letters used.
GRID TABLES: *Transverse Mercator Projection Tables, Ceylon Belt*
GRID "COLOR": Brown (red-brown)
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-YARD GRID (4-digit numerical reference):
Principal digits: (2); 100,000, 10,000

INDIA ZONE 1



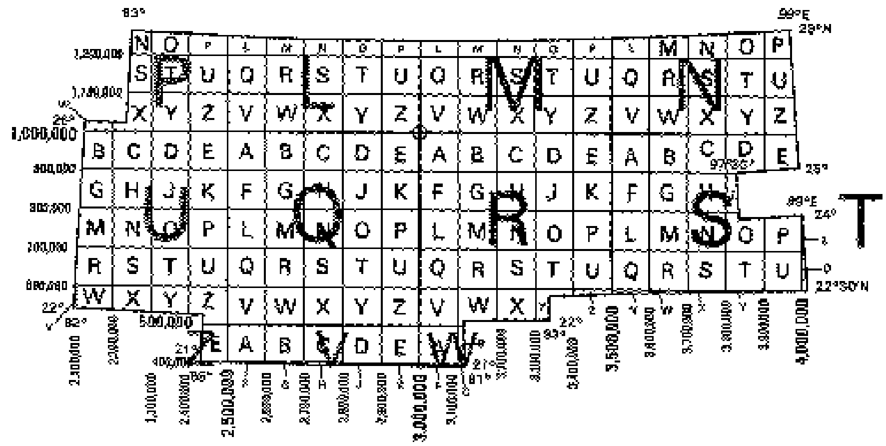
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 32° 30'N., 68°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone I*
GRID "COLOR": Black
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
Principal digits: (1); 10,000

INDIA ZONE IIA



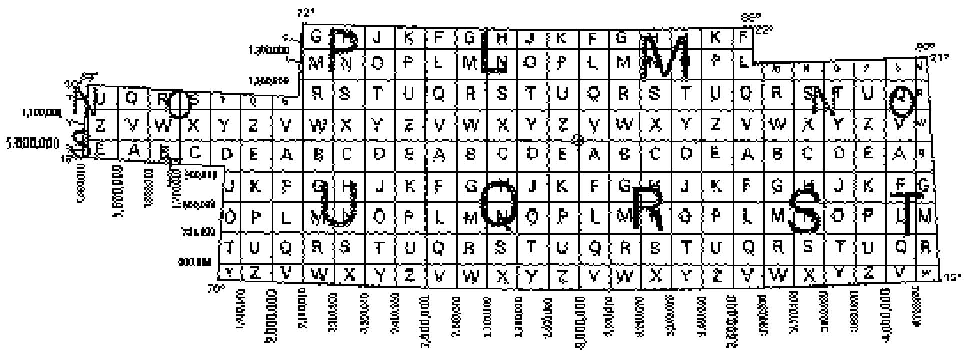
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 26°N., 74°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone IIA, India Zone IIB.*
GRID "COLOR": Black
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
Principal digits: (1); 10,000

INDIA ZONE IIB



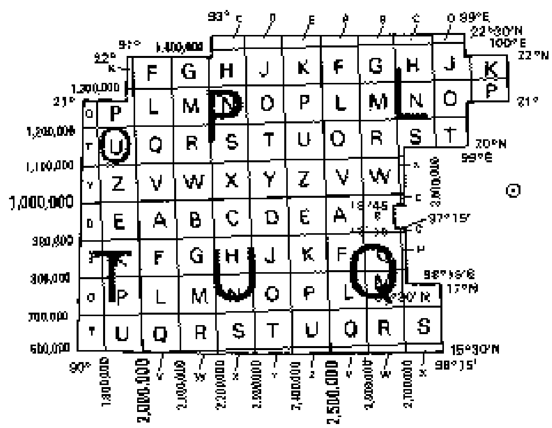
PROJECTION: *Lambert Conical Orthomorphic*
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 26°N.,90°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone IIA, India Zone IIB*
GRID "COLOR": Black
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
  Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
  Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
  Principal digits: (1); 10,000

INDIA ZONE IIIA



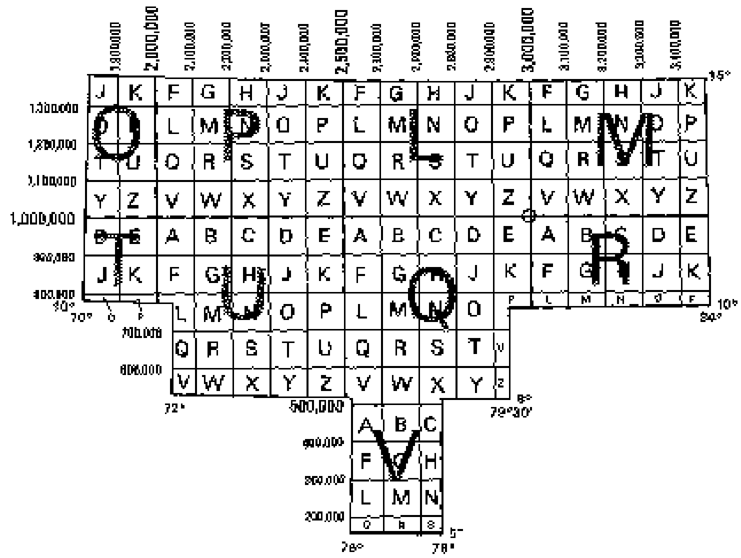
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 19°N., 80°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone IIIA, India Zone IIIB*
GRID "COLOR": Black
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
Principal digits: (1); 10,000

INDIA ZONE IIIB



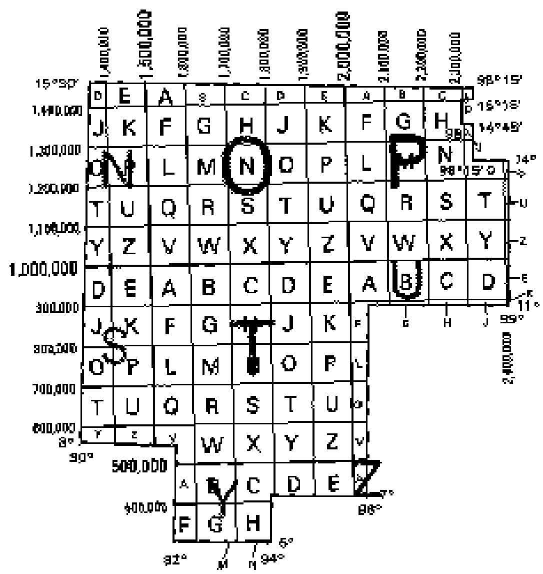
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 19°N., 100°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone IIIA, India Zone IIIB*
GRID "COLOR": Black
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
Principal digits: (1); 10,000

INDIA ZONE IVA



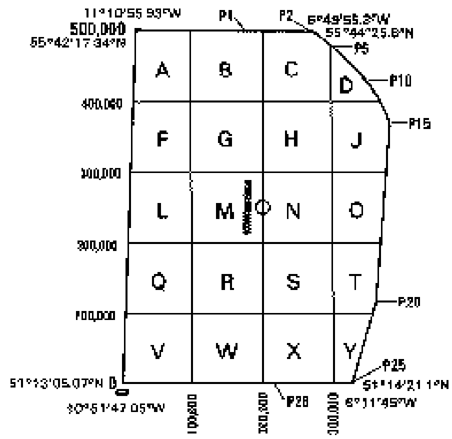
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 12°N., 80°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone IVA, India Zone IVB*
GRID "COLOR": Black
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
Principal digits: (1); 10,000

INDIA ZONE IVB



PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Everest (a = 6,974,310.6 Indian Yards 1/f = 300.8017)
UNIT: Indian Yard
ORIGIN: 12°N., 104°E.
FALSE COORDINATES OF ORIGIN: 3,000,000 yards E., 1,000,000 yards N.
SCALE FACTOR: .99878 6408
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, India Zone IVA, India Zone IVB*
GRID "COLOR": Blue
REFERENCING FOR 1,000-YARD GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-YARD GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-YARD GRID (2-digit numerical reference):
Principal digits: (1); 10,000

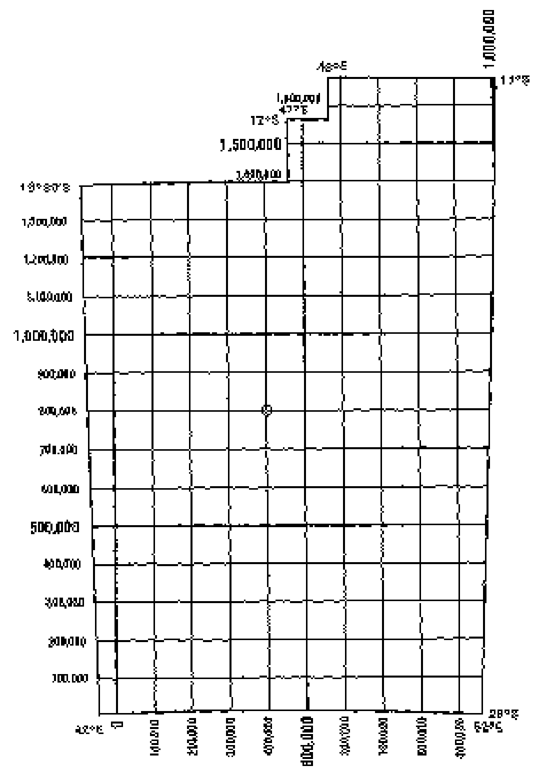
IRISH TRANSVERSE MERCATOR GRID



PROJECTION: Transverse Mercator
ELLIPSOID: Modified Airy
UNIT: Meter
ORIGIN: 53°30′N., 8°W.
FALSE COORDINATES OF ORIGIN: 200,000 meters E., 250,000 meters N. (south of the false origin add 1,000,000 meters to the northing.)
SCALE FACTOR: 1.00003 5
INCIDENCE OF GRID LETTERS: For the 500,000-meter square letter use the special letter I. Normal 100,000-meter square letters.
GRID TABLES: *Tables for the Transverse Mercator Projection of Ireland*
GRID "COLOR": Red (red-brown)
REFERENCING FOR 1,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-METER GRID (2-digit numerical reference):
Principal digits: (1); 10,000

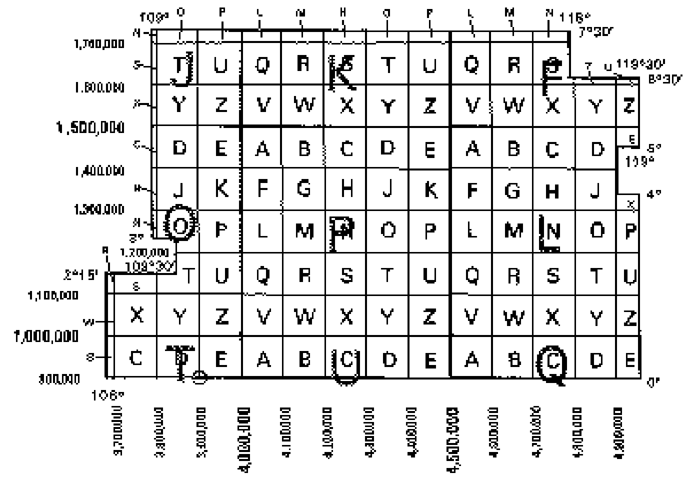
See British National Grid for Limits of Junction Line

MADAGASCAR GRID



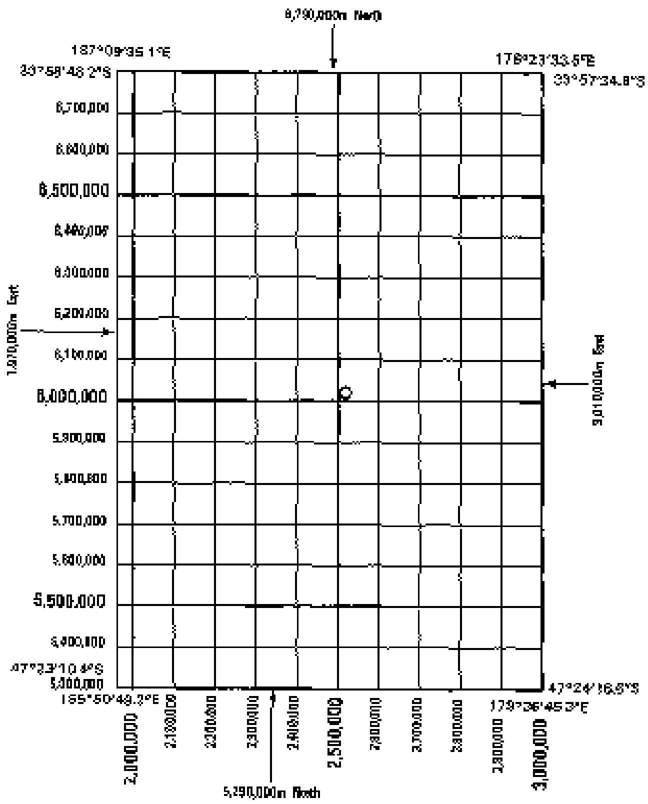
PROJECTION: Laborde
ELLIPSOID: International
UNIT: Meter
ORIGIN: 18°54'S., 46°26'13.95"E.
FALSE COORDINATES OF ORIGIN: 400,000 meters E., 800,000 meters N. (west of the false origin add 1,000,000 meters to the easting.)
SCALE FACTOR: .9995
INCIDENCE OF GRID LETTERS: No letters used
GRID TABLES: *Laborde Projection Tables, Madagascar Grid*
GRID "COLOR": Red (red-brown)
REFERENCING FOR 1,000-METER GRID (8-digit numerical reference):
Principal digits: (3); 100,000, 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-METER GRID (4-digit numerical reference):
Principal digits: (2); 100,000, 10,000

NETHERLANDS EAST INDIES
EQUATORIAL ZONE



PROJECTION: Mercator
ELLIPSOID: Bessel
UNIT: Meter
ORIGIN: Equator, 110°E.
FALSE COORDINATES OF ORIGIN: 3,900,000 meters E., 900,000 meters N.
SCALE FACTOR: .997
INCIDENCE OF GRID LETTERS: The 500,000-meter square letter P and the 100,000-meter square letter V are both east of the 4,000,000-meter grid line and north of the 1,000,000-meter grid line
GRID TABLES: *Lambert Conical Orthomorphic Projection Tables, Netherland East Indies Equatorial Zone*
GRID "COLOR": Blue
REFERENCING FOR 1,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-METER GRID (2-digit numerical reference):
Principal digits: (1); 10,000

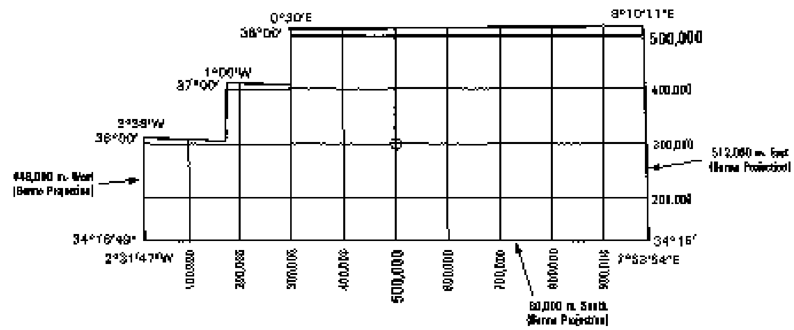
NEW ZEALAND MAP GRID (NZMG)



PROJECTION: New Zealand Map Grid (derived by W. I. Reilly)
ELLIPSOID: International
UNIT: Meter
ORIGIN: 41°S., 173°E.
FALSE COORDINATES OF ORIGIN: 2,510,000 meters E.; 6,023,150 meters N.
INCIDENCE OF GRID LETTERS: No letters used
GRID TABLES: Not available
GRID "COLOR": Blue
REFERENCING FOR 1,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 100,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000

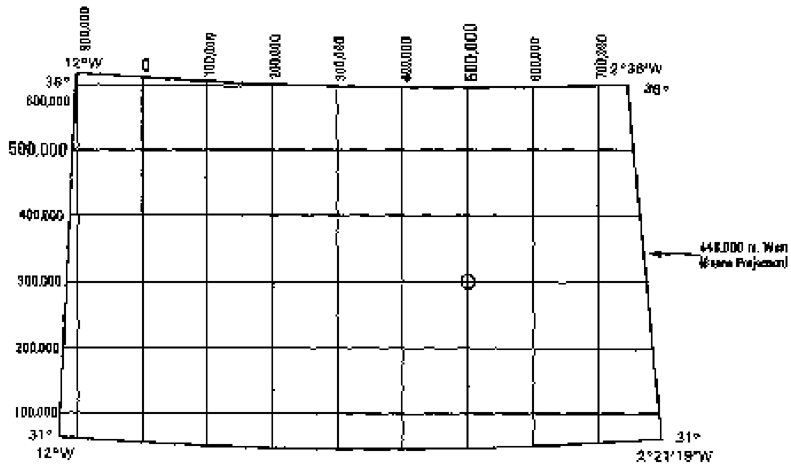
Page 4-21 New Zealand Map Grid (NZMG)

NORD ALGÉRIE GRID



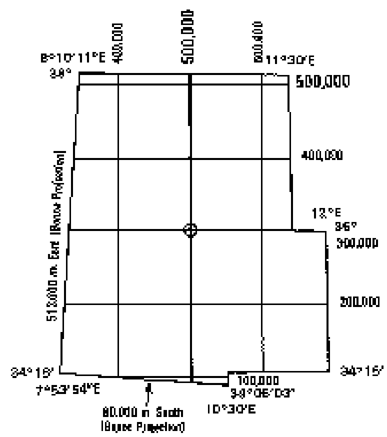
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Clarke 1880
UNIT: Meter
ORIGIN: 36°N., 2°42'E.
FALSE COORDINATES OF ORIGIN: 500,000 meters E.; 300,000 meters N.
SCALE FACTOR: .99962 5544
INCIDENCE OF GRID LETTERS: No letters used
GRID TABLES: *Tables des Constantes Numériques des Systèmes de Projections Lambert*
GRID "COLOR": Blue
REFERENCING FOR 1,000-METER GRID (8-digit numerical reference):
  Principal digits: (3); 100,000, 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
  Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-METER GRID (4-digit numerical reference):
  Principal digits: (2); 100,000, 10,000

NORD MAROC GRID



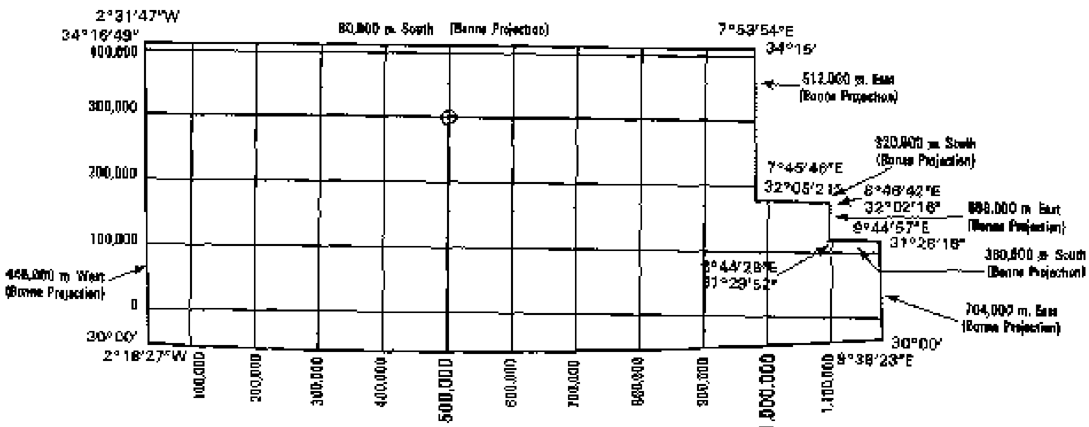
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Clarke 1880
UNIT: Meter
ORIGIN: 33°18'N., 5°24'W.
FALSE COORDINATES OF ORIGIN: 500,000 meters E., 300,000 meters N.
(west of the false origin add 1,000,000 meters to the easting)
SCALE FACTOR: .99962 5769
INCIDENCE OF GRID LETTERS: No Letters used.
GRID TABLES: *Tables des Constantes Numériques des Systèmes de Projections Lambert*
GRID "COLOR": Red (red-brown)
REFERENCING FOR 1,000-METER GRID (8-digit numerical reference):
Principal digits: (3); 100,000, 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-METER GRID (4-digit numerical reference):
Principal digits: (2); 100,000, 10,000

NORD TUNISIE GRID



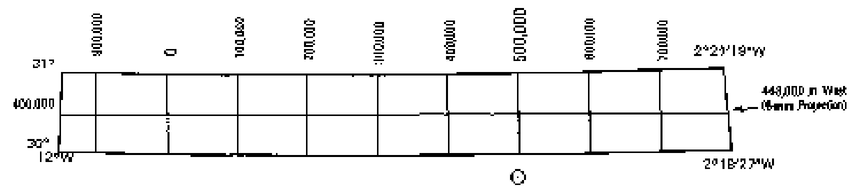
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Clarke 1880
UNIT: Meter
ORIGIN: 36°N., 9°54'E.
FALSE COORDINATES OF ORIGIN: 500,000 meters E., 300,000 meters N.
SCALE FACTOR: .99962 5544
INCIDENCE OF GRID LETTERS: No letters used.
GRID TABLES: *Tables des Constantes Numériques des Systèmes de Projections Lambert*
GRID "COLOR": Brown (red-brown)
REFERENCING FOR 1,000-METER GRID (8-digit numerical reference):
Principal digits: (3); 100,000, 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-METER GRID (4-digit numerical reference):
Principal digits: (2); 100,000, 10,000

SUD ALGERIE GRID



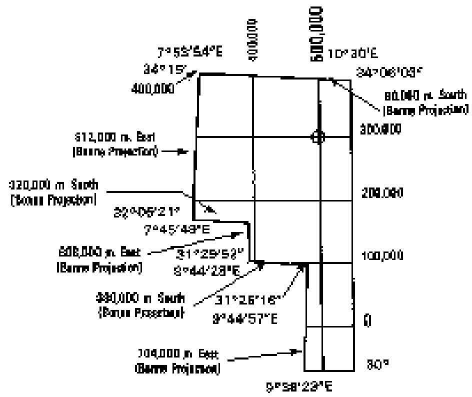
Page 4-25 Sud Algerie Grid

SUD MAROC GRID



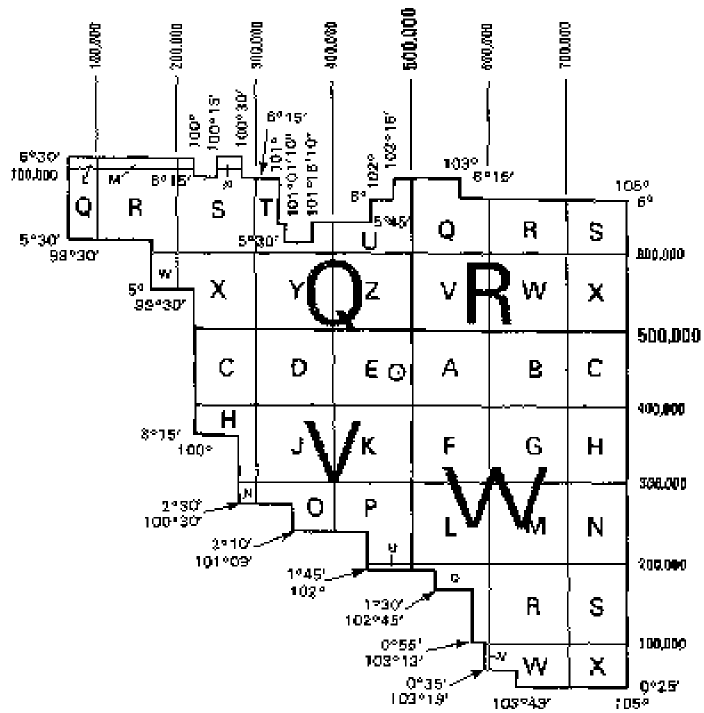
PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Clarke 1880
UNIT: Meter
ORIGIN: 29°42′N., 5°24′W.
FALSE COORDINATES OF ORIGIN: 500,000 meters E., 300,000 meters N. (west of the false origin add 1,000,000 meters to the easting).
SCALE FACTOR: .99961 5596
INCIDENCE OF GRID LETTERS: No letters used.
GRID TABLES: *Tables des Constantes Numériques des Systèmes de Projections Lambert*
GRID "COLOR": Blue
REFERENCING FOR 1,000-METER GRID (8-digit numerical reference):
Principal digits: (3); 100,000, 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-METER GRID (4-digit numerical reference):
Principal digits: (2); 100,000, 10,000

SUD TUNISIE GRID



PROJECTION: Lambert Conical Orthomorphic
ELLIPSOID: Clarke 1880
UNIT: Meter
ORIGIN: 33°18′N., 9°54′E.
FALSE COORDINATES OF ORIGIN: 500,000 meters E., 300,000 meters N. (South of false origin add 1,000,000 meters to the northing)
SCALE FACTOR: .99962 5769
INCIDENCE OF GRID LETTERS: No lettters used.
GRID TABLES: *Tables des Constantes Numériques des Systèmes de Projections Lambert*
GRID "COLOR": Blue
REFERENCING FOR 1,000-METER GRID (8-digit numerical reference):
Principal digits: (3); 100,000, 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 100,000, 10,000
REFERENCING FOR 100,000-METER GRID (4-digit numerical reference):
Principal digits: (2); 100,000, 10,000

WEST MALAYSIAN RSO GRID



PROJECTION: Rectified Skew Orthomorphic
ELLIPSOID: Modified Everest
UNIT: Meter
ORIGIN: 4°N., 102°15'E.
FALSE COORDINATES OF ORIGIN: 472,854 meters E., 442,420 meters N.
SCALE FACTOR: .99984
INCIDENCE OF GRID LETTERS: Normal
GRID TABLES: Not Available
GRID "COLOR": Black
REFERENCING FOR 1,000-METER GRID (6-digit numerical reference):
Principal digits: (2); 10,000, 1,000
REFERENCING FOR 10,000-METER GRID (4-digit numerical reference):
Principal digits: (1); 10,000
REFERENCING FOR 100,000-METER GRID (2-digit numerical reference):
Principal digits: (1); 10,000

CHAPTER 5 GEOGRAPHIC COORDINATE REFERENCES

5-1 USE.

The use of geographic coordinates as a system of reference is accepted worldwide. It is based on the expression of position by latitude (parallels) and longitude (meridians) in terms of arc (degrees, minutes, and seconds) referred to the Equator (north and south) and a prime meridian (east and west).

5-2 THE GEOGRAPHIC REFERENCE.

The degree of accuracy of a geographic reference is influenced by the map scale and accuracy requirements for plotting and scaling purposes.

```
Examples of references are:

     40°N 132°E (in degrees of latitude and longitude)
     40°21'N 132°14' (To minutes of latitude and longitude)
     40°21'12"N 132°14'18"E (To seconds of latitude and longitude)
     40°21'12.4"N 132°14'17.7"E (To tenths of seconds of latitude and
longitude)
     40°21'12.45"N 132°14'17.73"E (To hundredths of seconds of latitude
and longitude)
```

5-3 GEOGRAPHIC COORDINATES ON MAPS AND CHARTS.

5-3.1 U.S. military maps and charts include a graticule (parallels and meridians) for plotting and scaling geographic coordinates. Graticule values are shown in the map margin.

5-3.2 On most maps and charts at the scale of 1:1,000,000, the parallels and meridians are shown by intersections or full lines at one-degree intervals. The intersections or lines are labeled in degree values.

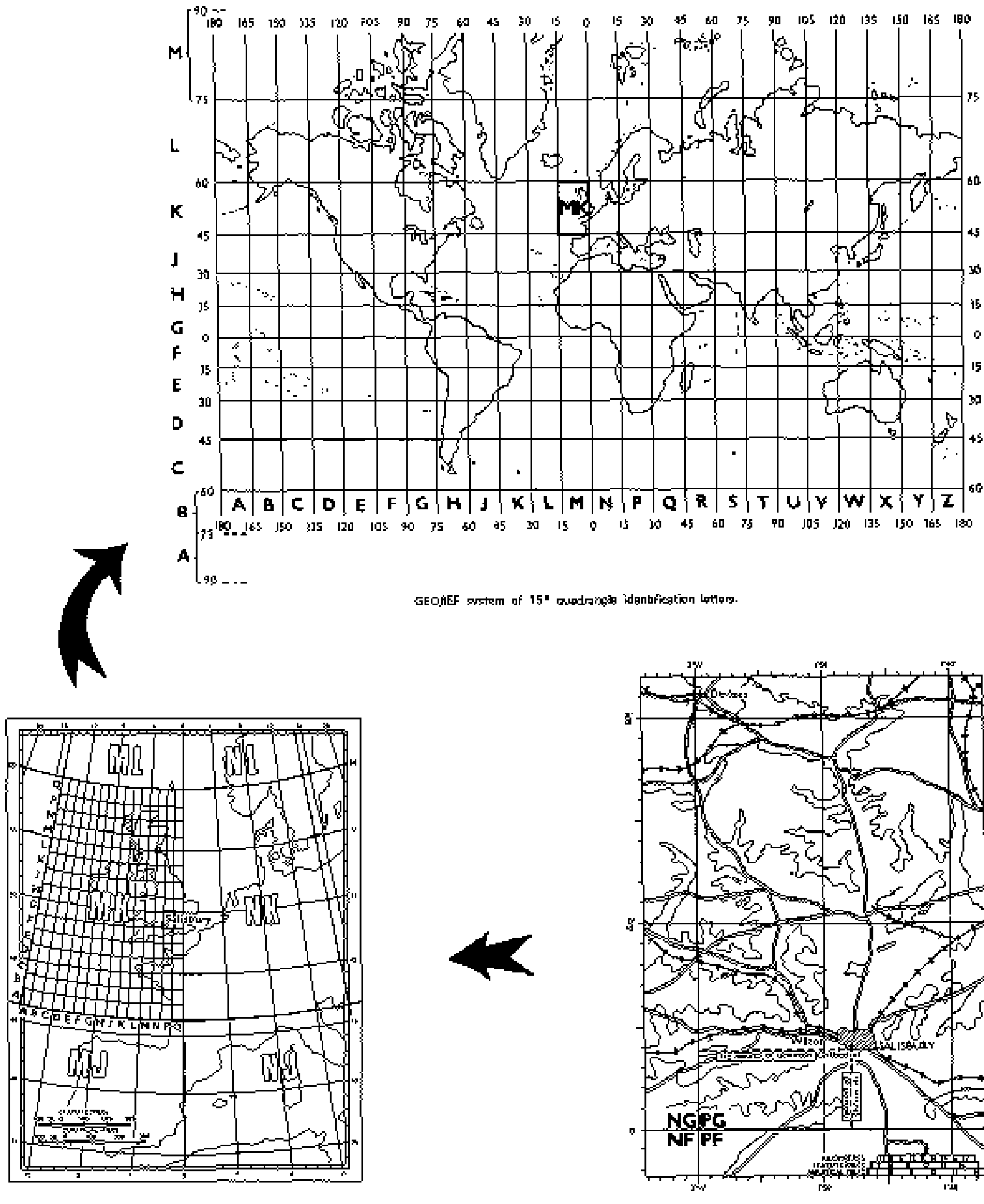
5-3.3 On maps and charts at the scale of 1:500,000, parallels and meridians are shown by full lines at 30-minute intervals. The full degree lines are labeled in degree values; the intermediate lines are labeled in minutes only.

5-3.4 On maps and charts at scales of 1:250,000 and larger the graticule may be indicated in the map interior by lines or ticks at prescribed intervals. The following indicates these intervals:

Scale	Tick Interval	Labeling at Corners[1]	Labeling of ticks
1:250,000	15 minutes	Degrees-minutes	15 minutes
1:100,000	10 minutes	Degrees-minutes	10 minutes
1:50,000	1 minute	Degrees-minutes-seconds	5 minutes
1:250000	1 minute	Degrees-minutes-seconds	5 minutes
1:12,500	1 minute	Degrees-minutes-seconds	1 minute

Table 7. Corner Labeling on Topographic Maps.

1 When departing from standard sheet lines to avoid unnecessary sheets or because of datum changes, corners are labeled to 1 second for 1:250,000 and 1:100,000 scale and to 0.1 second for 1:50,000 to 1:12,500 scale.



GEOREF system of 15° quadrangle identification letters.

GEOREF one degree quadrangle identification letters

GEOREF map reference

Figure 12. World Geographic Reference (GEOREF) System.

5-3.5 On Joint Operations Graphics (JOG), between O° and 76°, meridians are shown by full lines at 15-minute intervals with 1-minute ticks. Between 76° and 84° North and between 76° and 80° South, meridians are shown by full lines at 30 minute intervals with 1-minute ticks.

5-4 THE WORLD GEOGRAPHIC REFERENCE SYSTEM

5-4.1 The World Geographic Reference System (GEOREF) is a system used for position reporting. It is not a military grid, and therefore does not replace existing military grids. It is an area-designation method used for interservice and interallied position reporting for air defense and strategic air operations. Positions are expressed in a form suitable for reporting and plotting on any map or chart graduated in latitude and longitude regardless of map projection.

5-4.2 The system divides the surface of the earth into quadrangles, the sides of which are specific arc lengths of longitude and latitude; each quadrangle is identified by a simple systematic letter code giving positive identification with no risk of ambiguity.

5-4.2.1 There are 24 longitudinal zones each of 15 degrees width extending eastward from the 180° meridian around the globe through 360 degrees of longitude. These zones are lettered from A to Z inclusive (omitting I and O). There are 12 bands of latitude each of 15 degrees height, extending northward from the South Pole. These bands are lettered from A to M inclusive (omitting I) northward from the South Pole. This code divides the earth's surface into 288 15 degree quadrangles, each of which is identified by two letters. The first letter is that of the longitude zone and the second letter that of the latitude band. Thus the major part of the United Kingdom is in the 15 degree quadrangle MK. See figure 12.

5-4.2.2 Each 15 degree quadrangle is sub-divided into 15 one degree zones of longitude, eastward from the western meridian of the quadrangle, these one degree units being lettered from A to Q inclusive (omitting I and O). Each 15 degree quadrangle is also subdivided into 15 one degree bands of latitude northward from the southern parallel of the quadrangle, these bands being lettered from A to Q inclusive (omitting I and O). A one degree quadrangle anywhere on the earth's surface may now be identified by four letters. Salisbury therefore is in the one degree quadrangle MKPG. See figure 12.

5-4.2.3 Each one degree quadrangle is divided into 60 minutes of longitude, numbered eastward from its western meridian, and 60 minutes of latitude, numbered northward from its southern parallel. This direction of numbering is used wherever the one degree quadrangle is located,i.e., it does not vary even though the location may be west of the prime meridian or south of the equator. A unique reference defining the position of a point to an accuracy of one minute in latitude and longitude (i.e., 2 kms or less) can now be given by quoting four letters and four numerals. The four letters identify the one degree quadrangle. The first two numerals are the number of minutes of longitude by which the point lies eastward of the western meridian of the one degree quadrangle, and the last two numerals are the number of minutes of latitude by which the point lies northward of the southern parallel of the one degree quadrangle. if the number of minutes is less than 10 minutes, the first numeral will be a zero and must be written, e.g., 04. The GEOREF of Salisbury Cathedral is MK PG 12 04. See figure 12.

5-4.2.4 Each of the one degree quadrangles may be further divided into decimal parts (1/10 th and 1/100 th) eastward and northward. Thus, four letters and six numerals will define a location to 0.1-minute; four letters and eight numerals will define a location to 0.01-minute.