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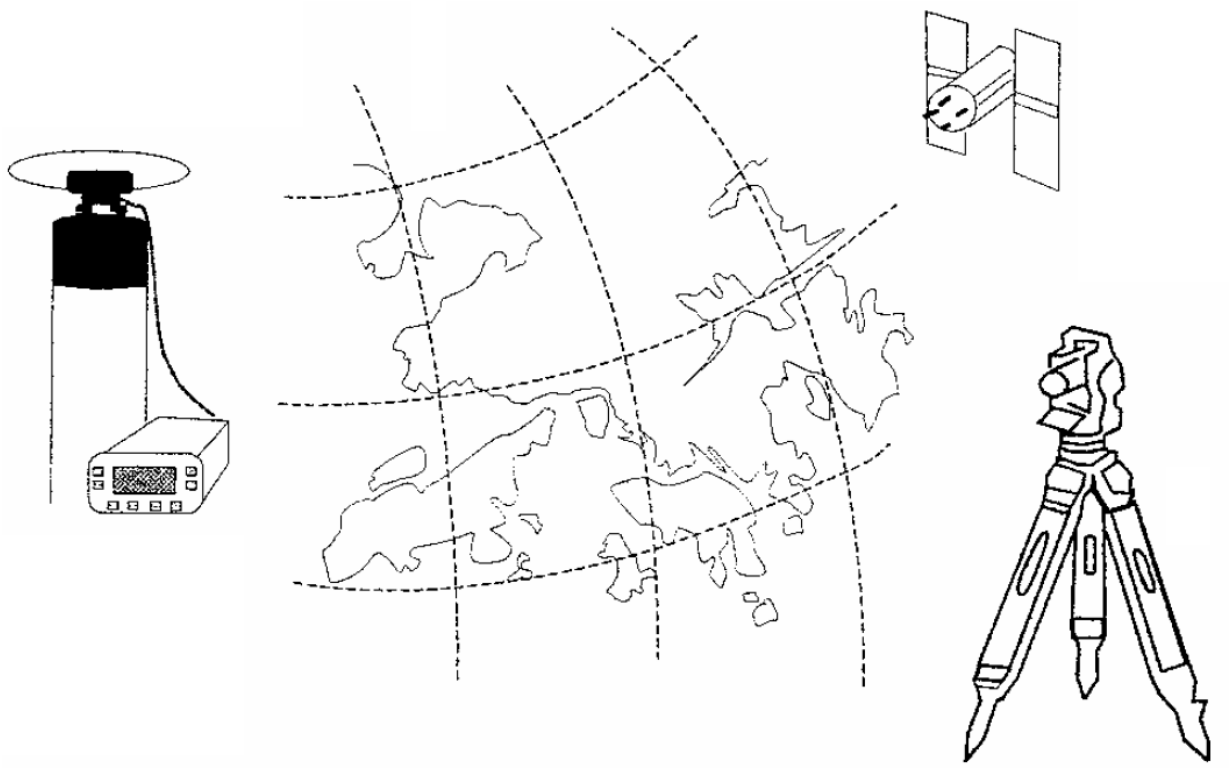
Explanatory Notes on Geodetic Datums in Hong Kong



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1.0	Initial Release	14-Nov-1995
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APPENDICES

INTRODUCTION

With the advent of technologies, fixing position to 5 to 100 metres accuracy is no longer difficult by using Global Positioning System (GPS) receivers. Higher accuracy in position fixing by GPS can also be obtained by longer observation time, applying differential corrections and computing the co-ordinates by post-processing method.

However, users are very often confused by various geodetic datums and grid systems presented on maps and plans. This booklet introduces the particulars of various geodetic datums and grid systems being used in Hong Kong without going into technical aspects deeply. Conversion formulae and parameters are also given in appendices to facilitate users to convert the co-ordinates of a point between various datums. Users should be aware that these conversion information will only give the computed co-ordinates to an accuracy specified of 2 to 5 meters or less than that of the original co-ordinates.

HISTORICAL BACKGROUND

Triangulation stations first appeared on the map of Hong Kong produced in 1845.

A map was produced by Mr. Tate in 1899/1900 and another one was compiled by Mr. W. J. Newland in 1903/1904. Although triangulation stations are shown on these maps, there is no survey record found for the triangulation.

In 1928/29 a military map of scale 1/20,000 was produced from air photographs taken in 1924/25 by the R.A.F. with ground controls provided by the 2nd Colonical Survey Section R.E. These ground controls were adjusted by the Geographical Section in 1928-30 and were later re-adjusted by the Crown Lands and Survey Office in 1946. It was adopted as the Main Triangulation of Hong Kong on which all surveys were based up to 1963.

In 1963, a re-triangulation was carried out because the network of that time could not meet the requirements for large scale mapping and cadastral surveys. The Hong Kong (1963) Datum was established using Clarke (1858) as the reference ellipsoid and Patridge Hill as origin of the local Datum. A plane rectangular grid system was developed using " Cassini " projection with grid origin in the southwest of Lantau Island to enable the co-ordinates in the Hong Kong territory were all positive values.

In line with the metrication policy in the 1970s, the Imperial grid was converted to metric unit of measure in 1975-77 with the grid origin further shifted 3550 meters to the east.

With the introduction of electro- magnetic distance measuring instrument, the distances between hilltop triangulation control points were resurveyed in 1978-79 to improve the consistence and accuracy of the control network. In this re-survey, a new geodetic datum, HK80 Geodetic Datum using International Hayford (1910) as the reference ellipsoid and the same projection origin was adopted. In the same time, Transverse Mercator projection was used for the rectangular grid system which was known as the Hong Kong 1980 Grid.

In 1990, the Survey & Mapping Office, Lands Department started to apply the GPS technique for fixing position of survey control points. A territory wide observation on a network of fifteen stations (twelve of which are at existing trig stations) was carried out by the No. 512 Specialist Team, Engineers of the U.K. Military Survey using GPS and Doppler satellite techniques. The network was adjusted with the results of high accuracy order. This survey provided a rigid link between the local HK80 Geodetic Datum and the global WGS84 Datum.

Since position of a point can be easily fixed by small GPS receivers on WGS84 Datum, the latitude, longitude and Universal Transverse Mercator projection (UTM) co-ordinates shown on the small maps are now based on this global datum to facilitate general users for hiking, boating, rescue, navigation purpose.

GEODETIC DATUMS

An ellipsoid defined with orientation and position as well as size and shape is known as geodetic datum. A geodetic datum can be a local datum for an area by defining the geodetic position and azimuth of a point as the origin in that area. The datum can also be a global datum if it is defined by the geocentre of the Earth mass.

There are two geodetic datums currently in use for horizontal control in Hong Kong. They are the local datum – Hong Kong 1980 Geodetic Datum (HK80), and the global datum – the World Geodetic System (WGS84). Details of these datums are described in the following sections and illustrated in the diagrams at appendix C1.

Hong Kong 1980 Geodetic datum (HK80)

The reference ellipsoid for HK80 is the International Ellipsoid (Hayford 1910).

The origin is at the old Trig " Zero " (now gone), which was 38.4 feet due south along the Transit Circle of the Hong Kong Observatory in Kowloon. As the latitude of the Hong Kong Observatory determined by astronomical observations was 22°18'13.20 " N, the latitude of the Trig " Zero " was thus 22°18'12.82 " N.

The Longitude of the Trig " Zero " was 114°10'18.75 " E which was determined in 1924 from simultaneous observations of Bordeaux signals made at Greenwich and Hong Kong.

The Amizuth adopted was the line from Trig 67.2 to Trig 94 (i.e. Tai Mo Shan to Au Tau) at 292°59'46.5 " which corresponded with the azimuth from old Trig 67 (now lost) to Trig 94 at 292°52'58.4 " . The latter value was determined by astronomical observations in February 1960 by a team of visiting Geodesists who assessed the accuracy to be ± 0.2".

World Geodetic System (WGS84)

WGS 84 is an earth-centred, earth-fixed Cartesian coordinate system. The origin of the system is at the geometric centre of the WGS84 Ellipsoid which also coincides with the Earth's centre of mass. The X-axis of this datum passes through the Greenwich meridian and the equator. The Y-axis forms a right-handed orthogonal plane on the equatorial plane. The Z- axis goes through the North Pole.

Due to different definitions of the two datums, the geodetic positions (i.e. latitude and longitude) and the UTM co-ordinates of a point will be slightly different. Details of the above datums are illustrated in the following tables and diagrams.

Datum Parameters

Datum	Hong Kong 1980 Geodetic Datum (HK80)	World Geodetic System (WGS84)
Ellipsoid	International Hayford (1910) Semi-major axis (a) = 6378388m Flattening (f) = 1 / 297.0	WGS84 Semi-major axis (a) =6378137 m Flattening (f) = 1 / 298.2572235634
Origin	Old trig " Zero " at Hong Kong Observatory Latitude 22° 18' 12.82 " N Longitude 114° 10' 18.75 " E	Centre of Earth mass
Azimuth	Trig 67.2 to Trig 94 292°59'46.5 "	Not applicable

MAP PROJECTION and GRID SYSTEM

A map projection is a representation of the latitude and longitude of the ellipsoidal Earth surface by a planar surface according to certain mathematical functions. As the projected graticules are not rectangular, a rectangular grid system will be further developed to facilitate large scale mapping, cadastral and engineering survey.

The Transverse Mercator is a conformal cylindrical projection which can be considered as a cylinder wrapping the Earth with its axis passes through the plane of equator. The Universal Transverse Mercator projection is a universal projection by rotating the cylinder around the earth with 6° interval in longitude. Refer appendix page C2.

Universal Transverse Mercator Grid (UTM Grid)

Hong Kong is in the Zone 49Q and Zone 50 Q of the UTM with 111°E and 117°E as the central meridians respectively. This Grid system can be found in all small scale maps in Hong Kong. To distinguish positions in different UTM Zones, each position is prefixed with its unique zone name. The UTM zones in Hong Kong using HK80 Datum are Zone 49Q GQ, HQ and Zone 50Q JV, KV. These prefixes are changed to Zone 49Q GE, HE and Zone 50Q JK and KK respectively under WGS84 Datum. (see appendix C5).

Hong Kong 1980 Grid (HK 1980 Grid)

The HK1980 Grid is a local rectangular grid system based on the HK80 Datum and Transverse Mercator projection. It is used in cadastral, engineering surveying and large scale mapping in Hong Kong. The origin of projection is at the old Trig 2 (now gone) and the scale factor is unity (1.0) along the central meridian.

This is a local rectangular grid system and is still in used for the above purposes. The latitude and longitude, and UTM graticule on WGS84 Datum is adopted in small scale maps for users' convenience. The projection parameters are illustrated in the table below.

Projection Parameters

Grid System	Universal Transverse Mercator Grid (UTM)		Hong Kong 1980 Grid System (HK 1980 Grid)
Projection	Transverse Mercator		Transverse Mercator
Geodetic Datum	HK80	WGS84	HK80
Reference Ellipsoid	International Hayford (1910)	WGS84 Ellipsoid	International Hayford (1910)
Origin of Projection	Zone 49Q Latitude Equator Longitude 111°E	Zone 50Q Equator 117°E	Old Trig 2 " Patridge Hill " Latitude 22° 18' 43.68 " N Longitude 114° 10' 42.80 " E
Grid Coord. of Origin	0 mN 500000 mE	0 mN 500000 mE	819069.80 mN 836694.05 mE
Scale Factor	0.9996 at the central meridian		Unity (1.0) along the central meridian at old Trig 2

VERTICAL DATUM

There are two vertical datum currently in use for vertical control in Hong Kong. They are the Principal Datum (HKPD) and the Chart Datum.

Hong Kong Principal Datum (HKPD)

In Hong Kong all heights and levels on land refer to the Principal Datum which is formerly known as Ordnance Datum. A vertical datum is usually determined with certain relationship to the mean sea level. The HKPD was previously determined as 1.125m below " Mean Sea Level " by Dr. Doberck for the years 1887-1888. This figure is superseded by the updated determination by Hong Kong Observatory derived using 19 years (1965-1983) observation records of the Automatic Tide Gauge situated at North Point, Victoria Harbour. It was then determined that the " Mean Sea Level " is approximately 1.23m above HKPD. Based on the tide data recorded by Quarry Bay tide gauge station in Victoria Harbour during the recent 19-year cycle (1997 to 2015), the mean sea level is about 1.30m above HKPD.

The original monument " Rifleman's Bolt " , is a copper bolt fixed in Hong Kong Naval Dockyard. The level of the " Bolt " was determined by H.M. Surveying Vessel " Rifleman " in 1866 as 5.435m above HKPD. Since then, the " Rifleman's Bolt " was used as a datum for all levelling. The bolt was latter removed from the original store house to the eastern wall of Blake Block in H.M.S. Tamar. The survey in May 1984 revealed that the level of the " Bolt " is 5.420m above HKPD. This monument is being preserved for its historical value and not to be used as a bench mark.

The Chart Datum (CD)

The Chart Datum, formerly known as Admiralty Datum, is approximately the level of Lowest Astronomical Tide and is adopted as the zero point for Tide Tables since 1917. All depths and submarine contours on Navigational Charts refer to the Chart Datum.

The Chart Datum is 0.15m below the Hong Kong Principal Datum. The relationship among different datums are summarized at page C2.

WGS84 Heights and HKPD Heights

The heights fixed by GPS are the ellipsoidal heights with reference to the WGS84 Datum. To convert the ellipsoidal heights to the heights above HKPD, the difference between these two vertical datums must be known. From the survey by UK Military 512 STRE in 1991, a rough relationship was deduced. It is noted that the WGS84 heights are generally higher than the HKPD heights with the magnitude of 2.4m in the west and 0.4m in the east of Hong Kong. The differences of these two datums are illustrated in the map at page C6. It is estimated that this relationship will give the height conversion to an accuracy of better than ±0.15m.

CONVERSION OF CO-ORDINATES

Users are reminded to confirm the geodetic datum of the co-ordinates input for the conversion. The information given below only serve as an approximate conversion to the accuracy generally 2m to 5m or that of the original co-ordinates whichever the less. For precise conversion, users may approach the Survey and Mapping Office for assistance.

The flow chart , formulae and parameters for the conversion of co-ordinates are shown on the pages C4, C7 to C9.

Latitude, longitude on HK80 Datum and WGS84 Datum

Due to the change of reference ellipsoid, the latitude, longitude on HK80 and WGS84 of a point are slightly different. As Hong Kong is a small area, additive constants for the geographic co-ordinates shown below are sufficient to attain the general accuracy.

longitude $_{HK80}$	=	longitude $_{WGS84}$	−	8.8 "	(corrected to nearest 0.1 ")
latitude $_{HK80}$	=	latitude $_{WGS84}$	+	5.5 "	(corrected to nearest 0.1 ")

UTM Grid co-ordinates on HK80 Datum and WGS84 Datum

Similarly, the UTM co-ordinates of a point on the two Datums are also slightly different. The conversion factors given below should be applied in the specified zone only. The conversion of UTM zones prefix can be referred to the map on appendix C5. The accuracy of these conversion factor should be about 5m.

Zone 49Q	UTM Easting $_{HK80}$	=	UTM Easting $_{WGS84}$	−	245m
	UTM Northing $_{HK80}$	=	UTM Northing $_{WGS84}$	+	195m
Zone 50Q	UTM Easting $_{HK80}$	=	UTM Easting $_{WGS84}$	−	260m
	UTM Northing $_{HK80}$	=	UTM Northing $_{WGS84}$	+	205m

Latitude, longitude and UTM co-ordinates

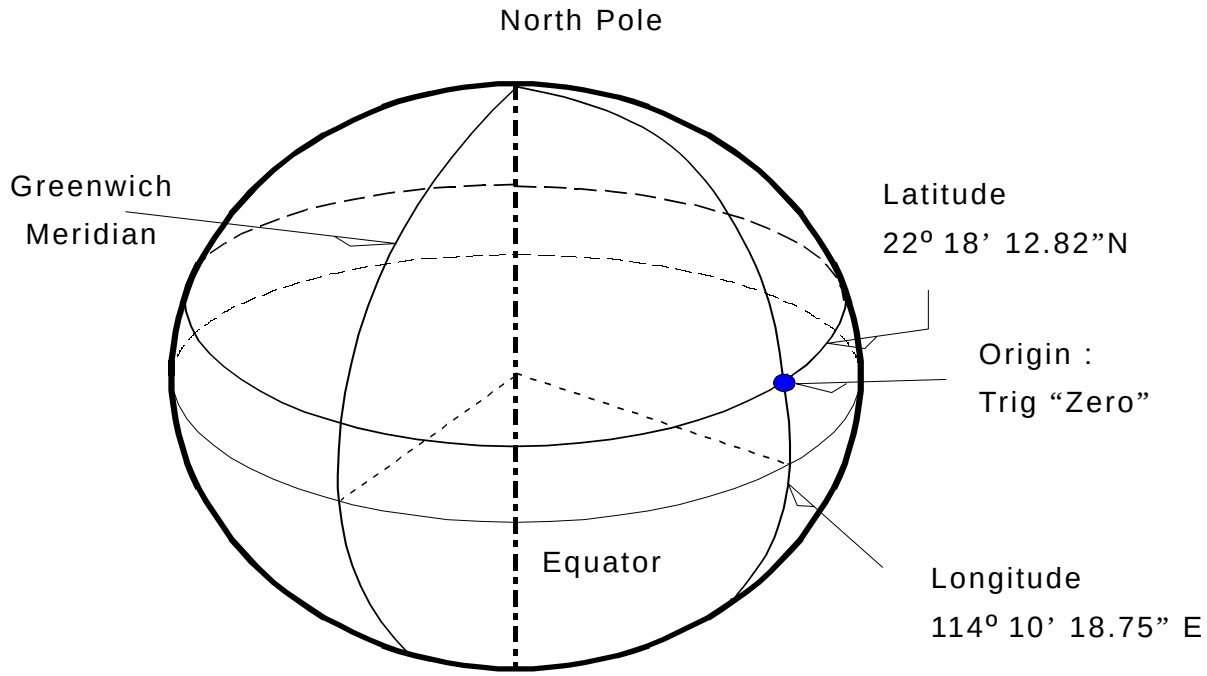
The conversion between the latitude, longitude and UTM Grid co-ordinates on either HK80 Datum or WGS84 Datum can be performed by using the projection formulae 1 to 3 or 3 to 5 and appropriate parameters. Users should be aware to apply appropriate parameters for different datums and check with the worked examples at page C9 to ensure the correctness of the conversion.

Latitude, longitude and HK1980 Grid co-ordinates

The conversion between the latitude, longitude (on HK80 Datum) and the HK 1980 Grid co-ordinates can be performed by the same projection formulae 1 to 3 or 3 to 5 with the projection origin at old Trig 2 and HK80 Datum parameters. WGS84 latitude, longitude can be computed by further applying the additive constants.

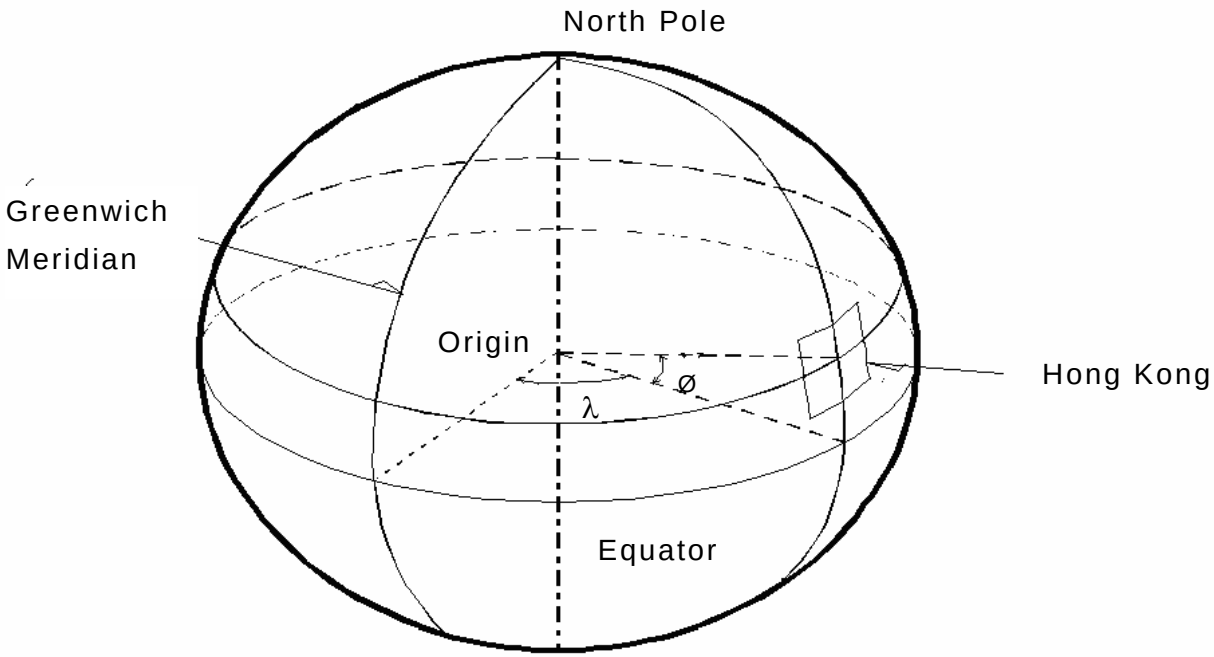
DIAGRAMS ILLUSTRATING

GEODETIC DATUMS



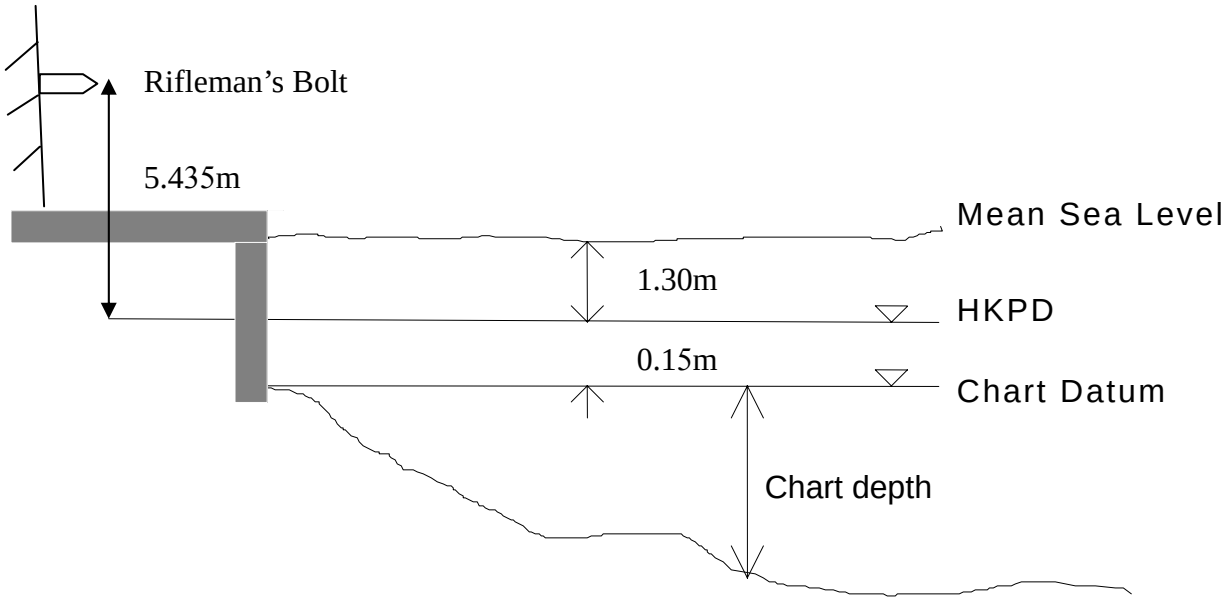
HK80 Geodetic Datum

Reference Ellipsoid : International Hayford (1910)

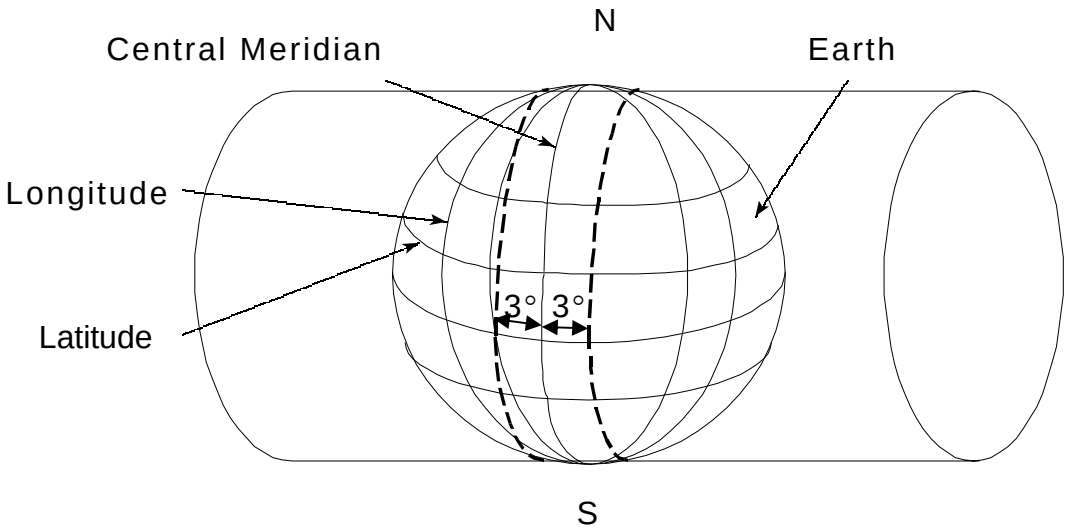


WGS84 Datum

Reference Ellipsoid: WGS 84



Vertical Datum

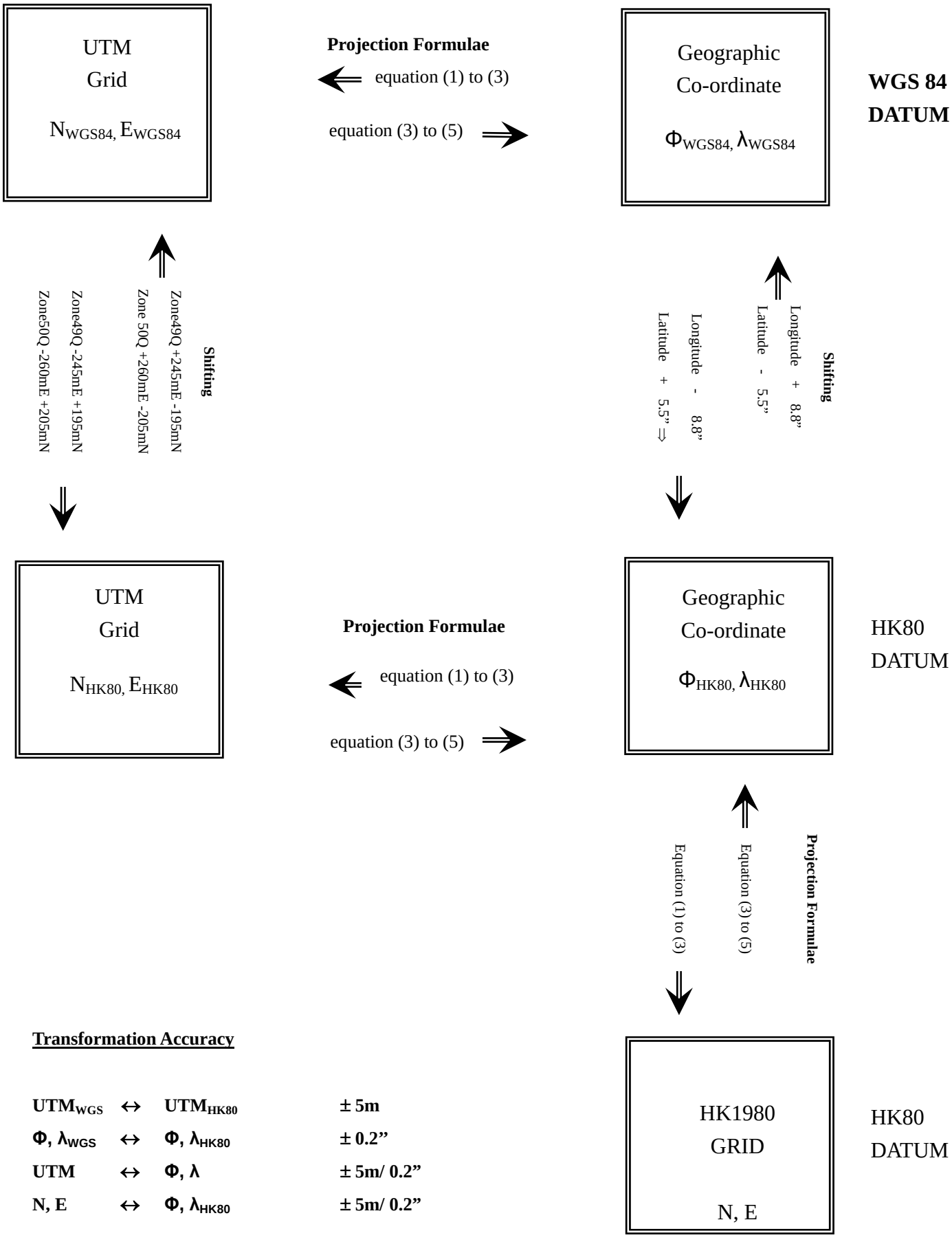


The Transverse Mercator Projection

Evolution of Hong Kong Geodetic Datums and Map Projections

Stage	Geodetic Datum	Projection and Local Grid System
Pre – 1963	**Reference Ellipsoid: Clark 1880** **Origin: Trig "Zero" 38.4 feet south of Hong Kong Observatory**	**Projection : Cassini** **Origin : Victoria Peak** **Co-ord : 5.18 ft N 0.38 ft E** **Grid Origin : Trig No. 1**
1963 **Re-triangulation**	**Reference Ellipsoid: Clark 1858** **Origin: Trig "Zero"**	**Projection : Cassini** **Origin : Victoria Peak** **Co-ord : 50000 ft N 120000 ft E** **False Grid Origin : southwest Lantau Island**
1976 **Metrication and co-ordinates transformation**	**Reference Ellipsoid: Clark 1858** **Origin: Trig "Zero"**	**Projection : Cassini** **Origin : Victoria Peak** **Co-ord : 15240 mN 33026 mE** **False Grid Origin : 3550m east of false origin of HK 1963 Grid**
1980 **Trilateration**	**Reference Ellipsoid: International Hayford (1910)** **Origin: Trig "Zero"**	**Projection : Transverse Mercator** **Origin : Trig No. 2 at Patridge Hill** **Co-ord : 819069.80 mN 836694.05 mE** **False Grid Origin : Same as HK1976 Grid**
1990 **GPS observation**	**No change in definitions of the local geodetic datum.** **Latitude, longitude and UTM Grid on WGS84 Datum are added to small scale maps for users' convenience.**	**No change of map projection, projection origin and grid origin for local rectangular grid system.**

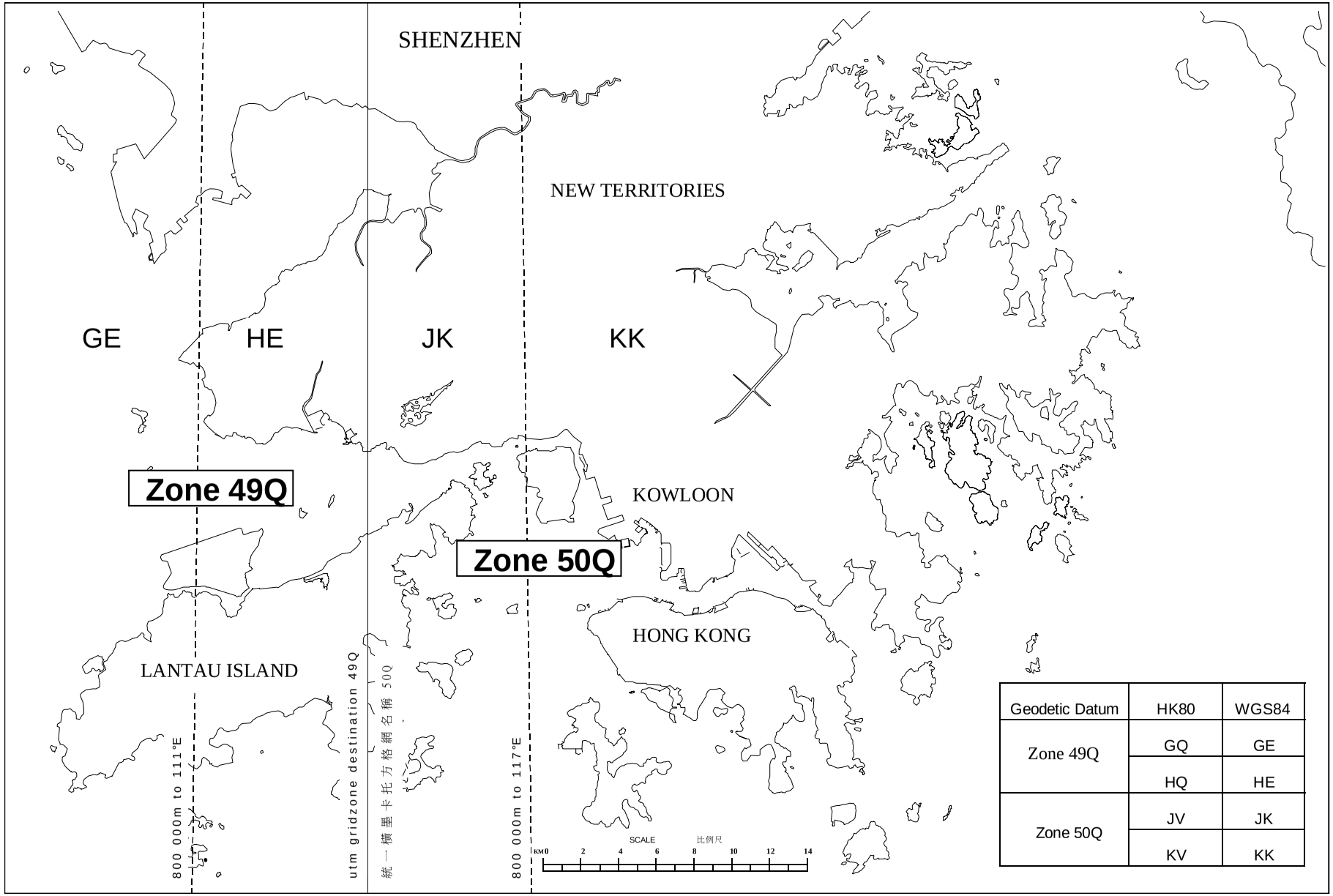
SCHEMATIC DIAGRAM SHOWING
TRANSFORMATION OF CO-ORDINATES OF GEODETIC DATUMS



Transformation Accuracy

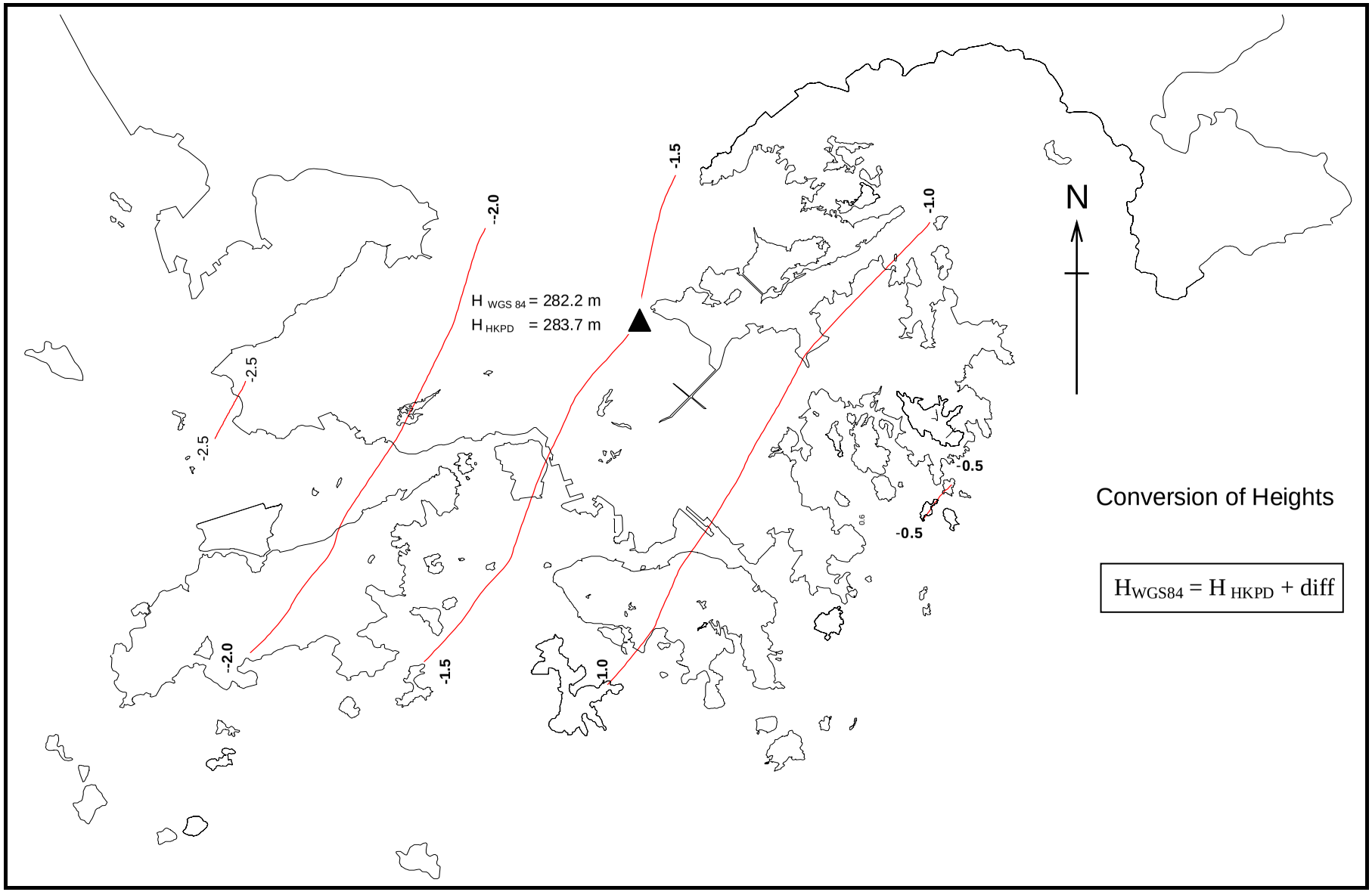
UTM_{WGS}	↔	**UTM_{HK80}**	**± 5m**
Φ, λ_{WGS}	↔	**Φ, λ_{HK80}**	**± 0.2"**
UTM	↔	**Φ, λ**	**± 5m/ 0.2"**
N, E	↔	**Φ, λ_{HK80}**	**± 5m/ 0.2"**

UTM Grid Zone in Hong Kong (WGS84 Datum)



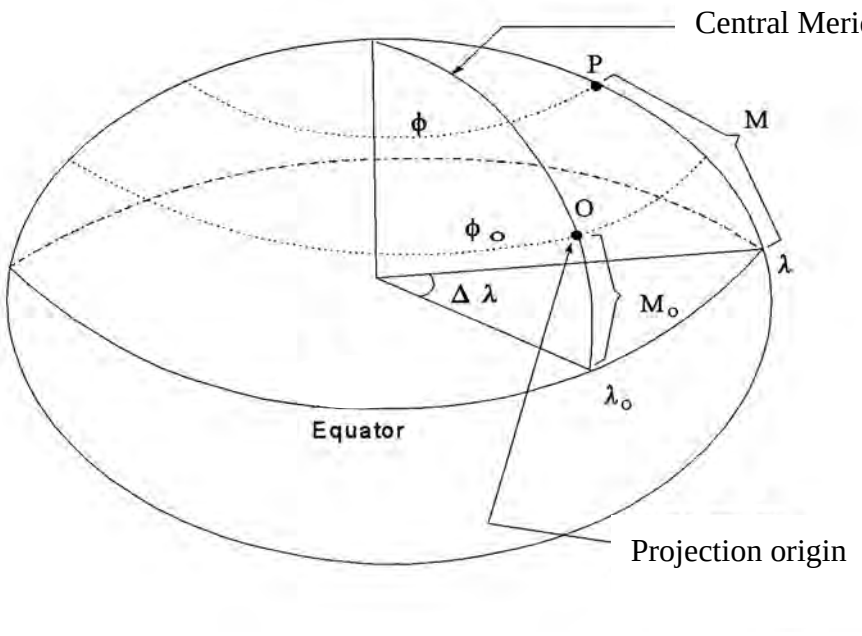
Geodetic Datum	HK80	WGS84
Zone 49Q	GQ	GE
	HQ	HE
Zone 50Q	JV	JK
	KV	KK

Contour Map Showing the Difference between Heights of WGS84 and Principal Datum



DEFINITIONS OF TERMS

Let P be the point to be converted.



N, E	=	Northing, Easting of P
N_0, E_0	=	Northing, Easting of projection origin O
Φ, λ	=	Latitude, Longitude of P
Φ_0, λ_0	=	Latitude, Longitude of projection origin O
m_0	=	scale factor on the central meridian
$\Delta\lambda$	=	longitude of P measured from central meridian in radian (i.e. $\lambda - \lambda_0$)
t	=	tan Φ
M	=	meridian distance measured from the Equator to P
M_0	=	meridian distance measured from the Equator to origin of projection
υ_s	=	radius of curvature in the prime vertical = $a / (1-e^2\sin^2\phi)^{1/2}$
ρ_s	=	radius of curvature in the meridian = $a(1 - e^2)/(1 - e^2\sin^2\phi)^{3/2}$
ψ_s	=	isometric latitude = υ_s / ρ_s
a	=	semi-major axis of the reference ellipsoid
f	=	flattening of the reference ellipsoid
e^2	=	first eccentricity of the reference ellipsoid = $2f - f^2$

Projection Formulae

Φ, λ to Grid co-ordinates

$$N = N_0 + m_0\{(M - M_0) + \upsilon_s (\sin \Phi) (\frac{\Delta\lambda^2}{2})(\cos \Phi)\} \quad \text{--(Eq. 1)}$$

$$E = E_0 + m_0\{\upsilon_s \Delta\lambda \cos \Phi + \upsilon_s \frac{\Delta\lambda^3}{6} (\cos^3 \Phi)(\psi_s - t^2) \} \quad \text{--(Eq. 2)}$$

Meridian distance, M

$$M = a [A_0'\Phi - A_2'\sin (2\Phi) + A_4' \sin (4\Phi)] \quad \text{--(Eq. 3)}$$

where $A_0' = 1 - \frac{e^2}{4} - \frac{3e^4}{64}$

$A_2' = \frac{3}{8}(e^2 + \frac{e^4}{4})$

$A_4' = \frac{15}{256} e^4$

Notes: 1. M_0 is computed using Eq. 3 by putting $\Phi=\Phi_0$ (Latitude of the projection origin.)
2. λ, Φ are in radian.

Grid Co-ordinates to Φ, λ

$$\lambda = \lambda_0 + \sec\Phi_\rho (\frac{\Delta E}{m_0 \nu_\rho}) - \sec\Phi_\rho (\frac{\Delta E^3}{6 m_0^3 \nu_\rho^3})(\psi_\rho + 2t_\rho^2) \quad \text{--(Eq. 4)}$$

$$\Phi = \Phi_\rho - (\frac{t_\rho}{m_0 \rho_\rho}) (\frac{\Delta E^2}{2 m_0 \nu_\rho}) \quad \text{--(Eq. 5)}$$

where $\Delta N = N - N_0$

$\Delta E = E - E_0$

and Φ_p is the latitude for which $M = (\Delta N + M_0) / m_0$

Notes: 1. Φ_p must be computed by iteration using Eq. 3.
2. All other quantities, such as t_p, ρ_p, υ_p, ψ_p have their usual meanings but are computed using Φ_p.

Parameters for Projection Formulae

Para.	WGS84 Datum (UTM ↔ Φ, λ)	HK80 Datum (UTM ↔ Φ, λ)	HK80 Datum (HK1980 Grid ↔ Φ, λ)
N_0	0m N	0m N	819 069.80m N
E_0	500 000m E	500 000m E	836 694.05m E
Φ_0	Zone 49Q: 0° Zone 50Q: 0°	Zone 49Q: 0° Zone 50Q: 0°	22°18'43.68"N
λ_0	Zone 49Q: 111°E Zone 50Q: 117°E	Zone 49Q: 111°E Zone 50Q: 117°E	114°10'42.80"E
m_0	0.9996	0.9996	1
M_0	0m	0m	2 468 395.728m
υ_s	6381215.957m	6381480.502m	6381480.502m
ρ_s	6344618.793m	6344727.809m	6344727.809m
ψ_s	1.005768221	1.005792635	1.005792635
a	6 378 137m	6 378 388m	6 378 388m
e^2	$6.69437999 \times 10^{-3}$	$6.722670022 \times 10^{-3}$	$6.722670022 \times 10^{-3}$

Notes: υ_s , ρ_s , ψ_s are parameters of a point near the centroid of Hong Kong and given to simplify the transformation.

Reference Example

Datum	Input Data		Result	
WGS84	Φ	22° 26' 01.26"N	UTM	2 483 566m N
	λ	114° 10' 29.31" E		209 194m E
	UTM	2 483 568m N	Φ	22° 26' 01.16" N
		209 192m E	λ	114° 10' 29.24" E
HK80	Φ	22° 26' 06.76" N	UTM	2 483 772m N
	λ	114° 10' 20.46" E		208 932m E
	Φ	22° 26' 06.76" N	HK1980	832 699m N
	λ	114° 10' 20.46" E	GRID	836 055m E
	UTM	2 483 775m N	Φ	22° 26' 06.89" N
		208 930m E	λ	114° 10' 20.39" E
	HK1980	832 699m N	Φ	22° 26' 06.76" N
	GRID	836 055m E	λ	114° 10' 20.45" E