Datums and Coordinate Systems

The Hartebeesthoek94 Datum is the official geodetic datum for South Africa. The datum was implemented in 1999 when it replaced the Cape Datum.

Name	Hartebeesthoek94 Datum
Abbreviation	Hart94
Reference	Ellipsoid WGS84
Reference Frame	ITRF91
Reference Epoch	1st January 1994

Background

Prior to 1st January 1999, the co-ordinate reference system, used in South Africa as the foundation for all surveying, engineering and georeferenced projects and programmes, was the Cape Datum . This Datum was referenced to the Modified Clarke 1880 ellipsoid and had its origin point at Buffelsfontein, near Port Elizabeth. The Cape Datum was based on the work of HM Astronomers: Sir Thomas Maclear, between 1833 and 1870, and Sir David Gill, between 1879 and 1907, whose initial geodetic objectives were to verify the size and shape of the Earth in the Southern Hemisphere and later to provide geodetic control for topographic maps and navigation charts.

From these beginnings, the network was extended to eventually cover the entire country and now comprises approximately 29 000 highly visible trigonometrical beacons on mountains, high buildings and water towers, as well as approximately 20 000 easily accessible town survey marks.

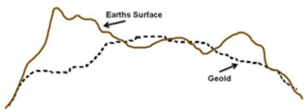
As with other national control survey networks throughout the world, which were established using traditional surveying techniques, flaws and distortions in these networks have become easily detectable using modern positioning techniques such as the Global Positioning System (GPS). In addition to these flaws and distortions, most national geodetic networks do not have the centre of their reference ellipsoids co-incident with the centre of the Earth, thus making them useful only to their area of application. The upgrading, recomputation and repositioning of the South African coordinate system was driven by the advancement of modern positioning technologies and the globalization of these techniques for navigation and surveying.

Since the 1st January 1999, the official co-ordinate system for South Africa is based on the World Geodetic System 1984 ellipsoid, commonly known as WGS84, with the International Terrestrial Reference Frame 1991 (ITRF91 (epoch 1994.0))coordinates of the Hartebeesthoek Radio Astronomy Observatory Telescope used as the origin of this system. This new system is known as the Hartebeesthoek94 Datum. At this stage all heights still remain referenced to mean sea level, as determined in Cape Town and verified at tide gauges in Port Elizabeth, East London and Durban.

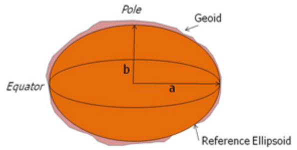
Geoids & Ellipsoids

The earth's physical surface is a tangible one encompassing the mountains, valleys, rivers and surface of the sea. It is highly irregular and not suitable as a computational surface. A more smoothed representation of the earth is the Geoid.

There are a number of definitions for this surface which can be described as follows: 'that surface that would be assumed by the undisturbed surface of the sea, continued underneath the continents by means of small frictionless channels.



The Ellipsoid is a smooth mathematical surface that best fits the shape of the geoid and is the next level of approximation of the actual shape of the earth.



Elements of an ellipse

a = Semi Major Axis

b = Semi Minor Axis

f = Flattening = (a-b)/a

PP' = Axis of revolution of the earth's ellipsoid

Below is a list of commonly used ellipsoids used in southern Africa and their associated parameters.

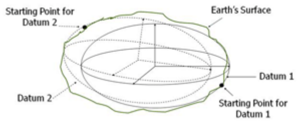
Ellipsoid	a	b	Unit	Used
Mod. Clarke 1880	6378249.145	6356514.967	International meters	R.S.A., Botswana, Zimbabwe
WGS 84	6378137.000	6356752.314	International meters	Globally
Bessel	6377397.155	6356078.963	German Legal meters	Namibia
Clarke 1866	6378206.400	6356584.467	International meters	Mozambique

Datums

A National geodetic co-ordinate system is related to its Geodetic Datum, which, in turn, is defined by the following:

1. A defined geodetic reference ellipsoid, in terms of the a,b or a,f parameters.
2. A defined orientation, position and scale of that Geodetic Datum in space.

From this it can be deduced that a specific ellipsoid can be used to define an infinite amount of datums. This is demonstrated in the figure below.



The Cape Datum

a) The Modified Clarke 1880 is the reference ellipsoid.

b) The initial point for the existing South African Datum is the Buffelsfontein trigonometrical beacon, near Port Elizabeth.

c) The orientation and scale characteristics were defined by periodic astronomic azimuth and base line measurements.

The Hartebeesthoek94 Datum

a) The WGS84 is the reference ellipsoid.

b) The initial point is the Hartebeesthoek Radio Astronomy telescope, near Pretoria.

c) The scale and orientation characteristics were defined within the GPS operating environment and has been confirmed to be co-incident with ITRF91 determination.

Ellipsoidal Coordinates

The three dimensional (real world) co-ordinates of a point on the earth's surface can be defined in:

Geographical co-ordinates

Latitude(Ø : angular displacement north/south of the equator.

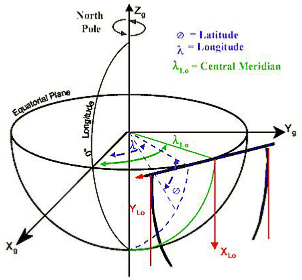
Longitude( ) : angular displacement east/west of the Greenwich meridian.

Height : (H) orthometric (height above mean sea level)

or (h) ellipsoidal (height above ellipsoid).

Geocentric Cartesian co-ordinates

A three-dimensional Cartesian co-ordinate system (Xg, Yg, Zg) with its origin coinciding with the centre of the reference ellipsoid/Earth, and axes as shown below.



The following are examples coordinates of three points in South Africa referenced to the Hartebeesthoek94 datum in:

Geographical co-ordinates (Ø, , H)

Durban	29° 57′ 54.04249" S	30° 56′ 48.02634" E	46.419
Pretoria	25° 43′ 55.30216" S	28° 16′ 57.47865" E	1387.341
Cape Town	33° 57′ 05.16921" S	18° 28′ 06.76131" E	83.730

Geocentric Cartesian co-ordinates (X,Y,Z)

Durban	4742985.565	2843868.499	-3167037.434
Pretoria	5064032.251	2724720.764	-2752951.003
Cape Town	5023564.635	1677795.097	-3542026.169

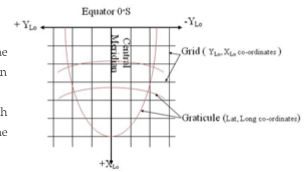
Gauss Conform co-ordinates (y, x, h)

Durban	Lo31°	5147.033	3316236.077	46.419
Pretoria	Lo29°	71984.489	2847342.740	1387.341
Cape Town	Lo19°	49126.565	3758401.865	83.730

Projected Coordinates

Plane co-ordinates are the simplest type of co-ordinates to use for everyday practical applications. To achieve this simplicity, the ellipsoidal latitude and longitude co-ordinates, or 3-D geocentric co-ordinates, must therefore be projected onto a plane surface. It is not possible to do this without some distortion. This can be demonstrated by cutting a tennis ball in half and attempting to flatten it.

Projections which have the properties of preserving angles and shapes are called Conformal or Orthomorphic projections. In South Africa the Gauss Conform Projection (modification of the Mercator projection) is used for the computation of the plane YLo and XLo co-ordinates, commonly known as the "Lo. co-ordinate system".



Here the equator will project as a straight line, at right angles to the central meridian (Lo.), but all other meridians and parallels will project as curved lines. The equator and the Lo. are the origins of the YLo and XLo axes of our plane rectangular co-ordinate system. The figure, above, shows the relationship between plane (Lo.) co-ordinates and geographical co-ordinates.

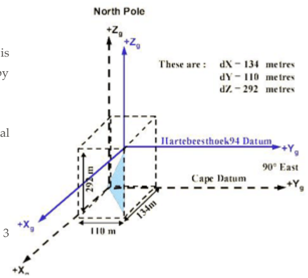
In the South African plane co-ordinate system only the area within one degree of longitude on either side of the central meridian is projected. The width of each segment, often referred to as a belt, is thus two degrees of longitude and is referred to the central meridian (CM) of that belt. Each zone is named after the longitude of origin i.e. Lo 17°, Lo 19°, Lo 21° etc.

X (Southings) coordinates are measured southwards from the equator , increasing from the equator (where X = 0m) towards the South Pole.

Y (Westings) coordinates are measured from the CM of the respective zone, increasing from the CM (where Y=0) in a westerly direction. Y is +ve west of the CM and -ve east of the CM.

Datum Relationships

At the most elementary level, a 2D Helmert Transformation (which uses 2 translations , rotation and scale factor) can be used to define the relationship between the two datums. This model is very effective over small areas (up to 40km) and should only be used when heights are not relevant.



A Geocentric Cartesian Translation, between the two datum's geocentres (dX ,dY, dZ), can also model the relationship between the two datums. This is commonly known as the Moledensky (3 Parameter) Transformation. The Chief Directorate: National Geospatial Information computed translation values by using the Hartebeesthoek94 Datum and the Cape Datum co-ordinates of a number of accurately determined trigonometrical beacons.

Note: These transformation parameters will yield co-ordinates in the other datum with residuals not exceeding 15 metres. This transformation is ideal for local areas where much better accuracies are attainable. The magnitude of these translations are :

dX = 134 m , dY = 110 m , dZ = 292 m

More complex models such the Bursa-Wolfe (7-Parameter) Transformation can be used to model the datum relationship. This model uses 3 translations, 3 rotations and scale and is more suitable for larger areas.