Building a Local Transverse Mercator (LTM) Grid aligned with MGA94 for use in GNSS and GIS

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Quickclose

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What is an LTM?

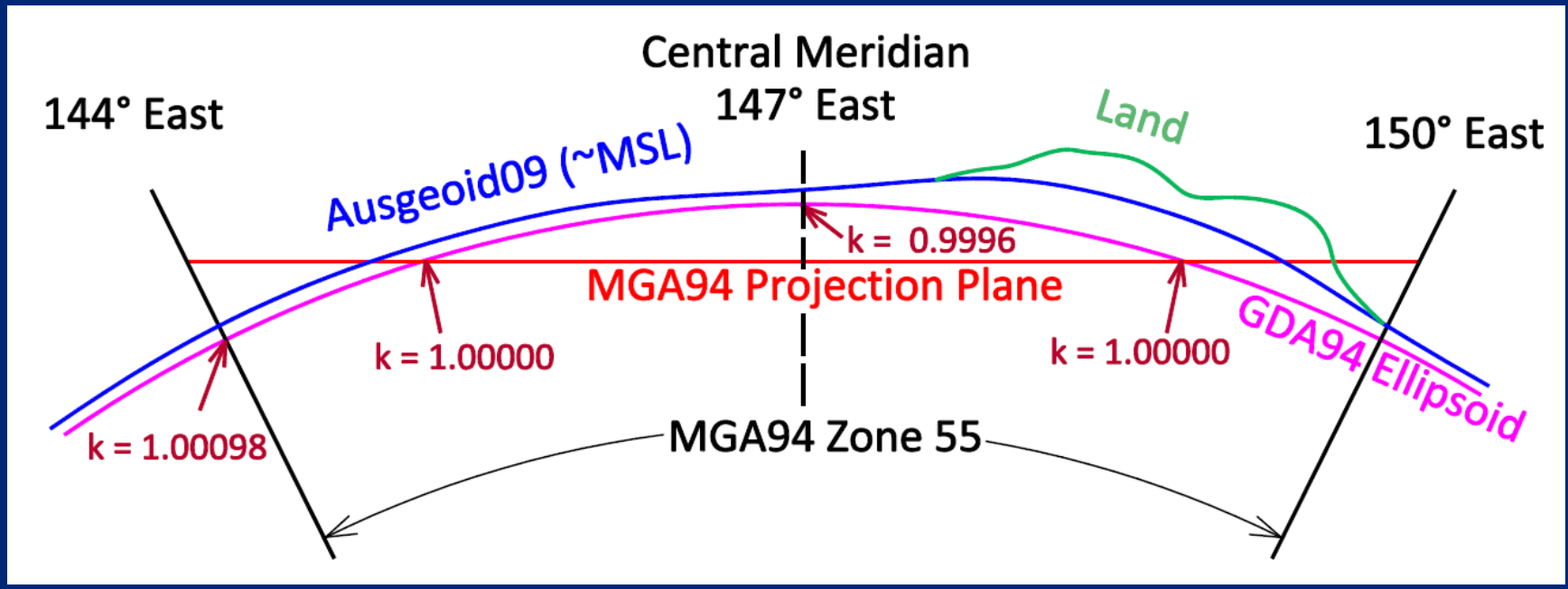
- An LTM (Local Transverse Mercator) is a working “Plane” Grid
- Used for cadastral surveys, engineering and construction
- Essential for surveys where dimensional precision better than 1:20,000 is required

A LTM or Plane grid aligned with MGA94 is ideal for most surveys

Why do we need a LTM aligned with MGA94?

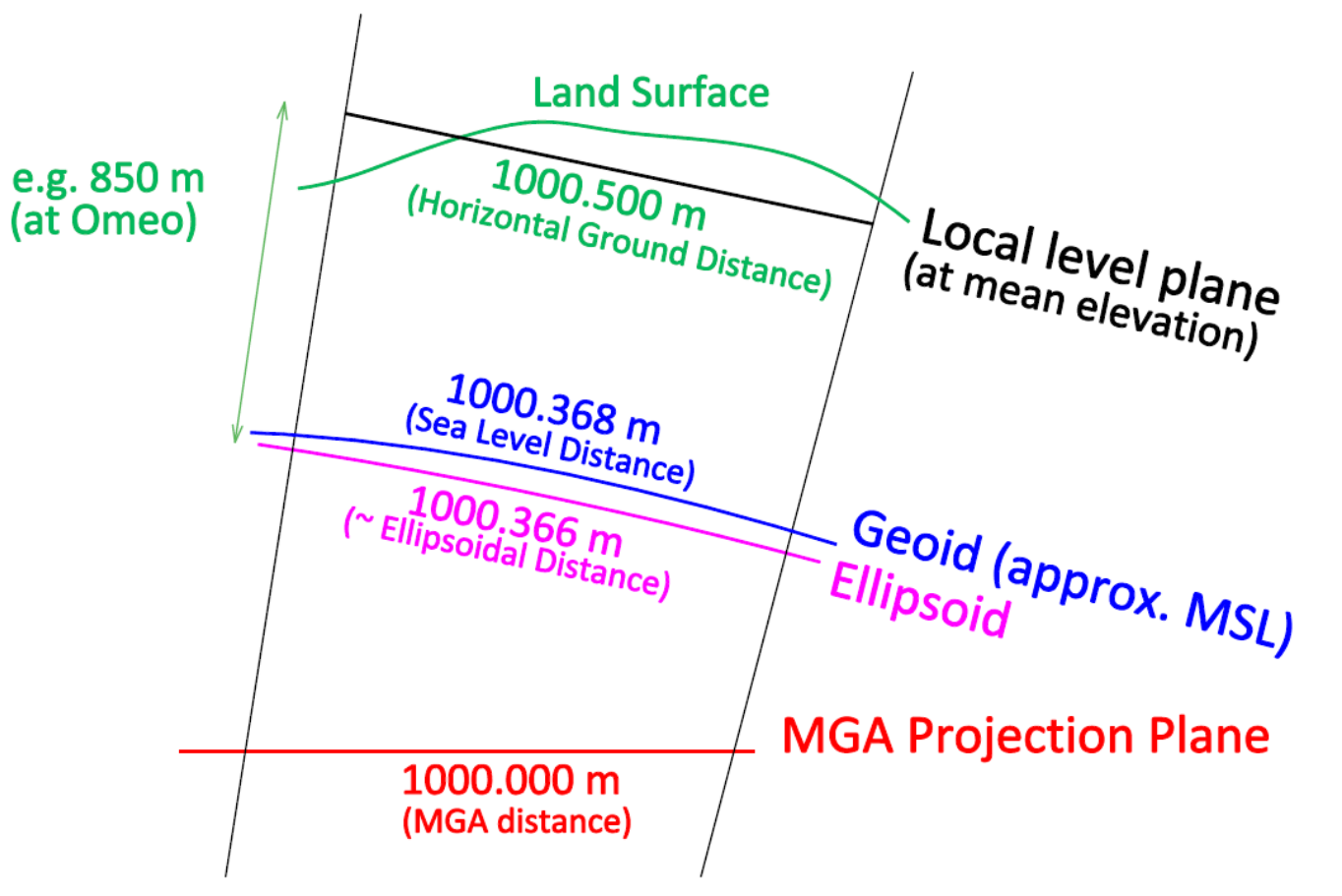
- If Ground distances are to be close to Grid distances
- If bearings are to be the same in local and MGA94 projections
- When using GNSS on cadastral and engineering surveys
- For setting up a local "Plane" grid system in a GIS or surveying software package with GDA94 ellipsoidal (geographic) coordinates
- Portability of a grid setup across different systems

Surfaces used in surveying



Different surfaces ➔ different distances!

Distances between two points can vary ...

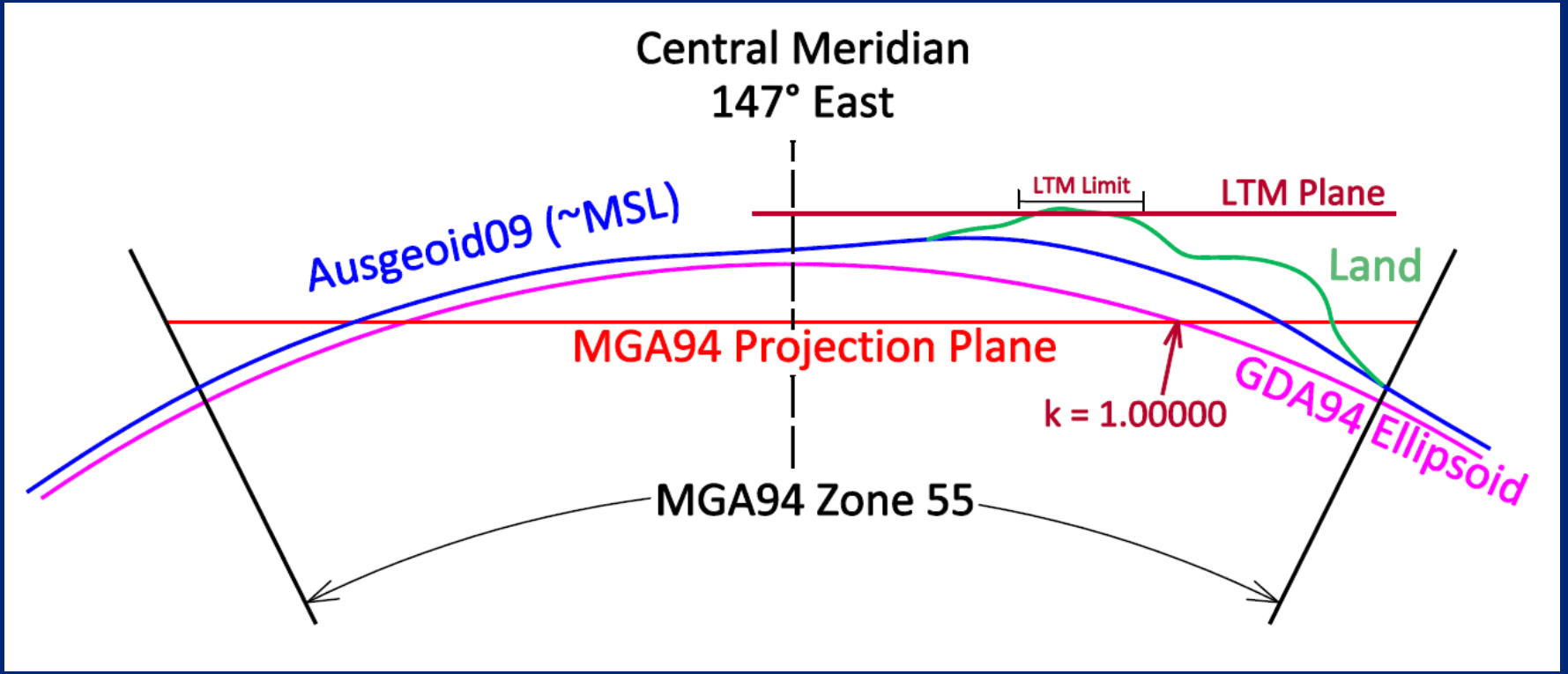


Ellipsoid distance / Grid distance = Grid Scale Factor (approx.) or LSF

Ground distance / Grid distance = Combined Scale Factor

Plane bearing = MGA94 bearing + rotation

Local Transverse Mercator (LTM) concept



Ground distance / LTM Grid (plane) distance = 1 (close to)

LTM Plane bearing = MGA94 Grid bearing

Comparing the LTM approach with Site Calibrations

- LTM is a rigorous, control free method of defining a local plane grid
- Site Calibrations (also called site transformation or localisation) are commonly used with GNSS (RTK) when used with established local grids

Site Calibrations are easy, but there are snags!

Site Calibration (localisation or site transformation)

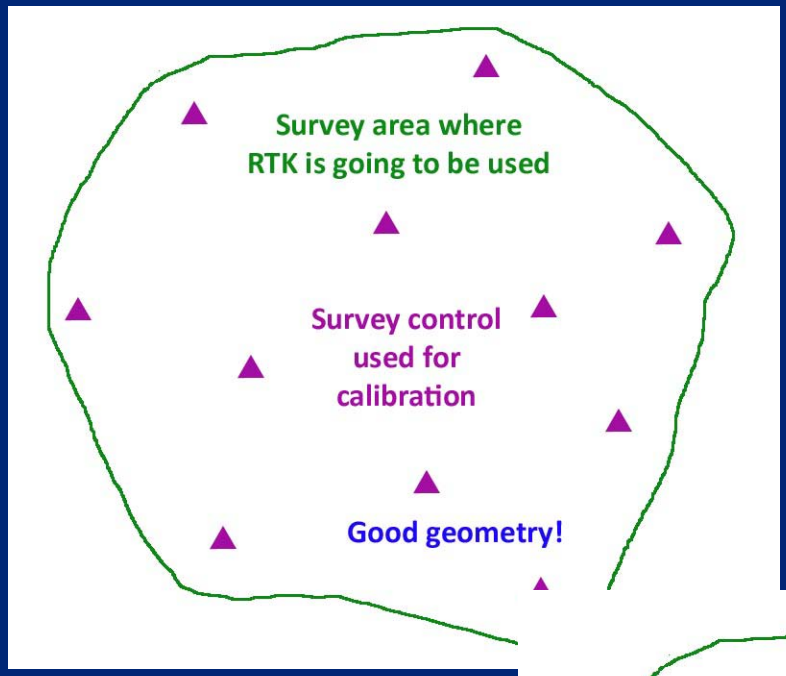
Benefits of using site calibration method

- Easy to setup in a GNSS system
- Accurate if geometry of calibration is good and existing control is of high quality

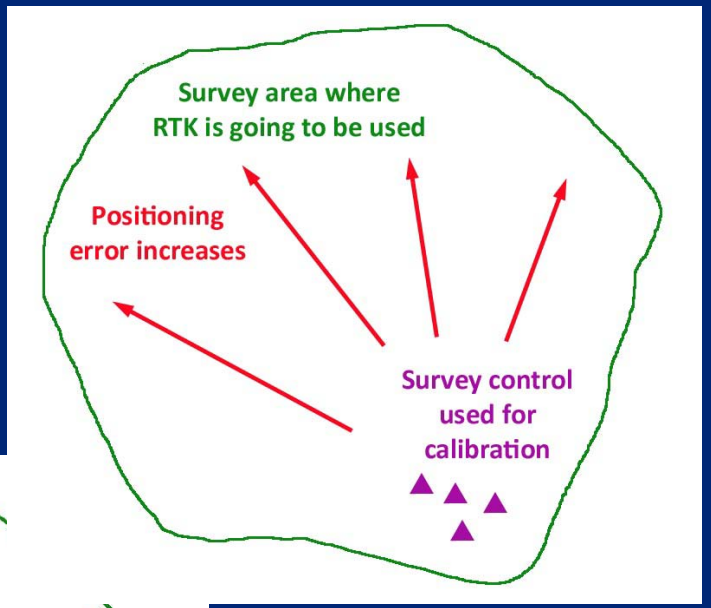
Disadvantages of the site calibration method

- Cannot be used on new sites where there is no existing control
- Propagates significant errors if the calibration geometry is poor
- Errors in coordinates or GPS fixing of the site control propagate into the transformation
- Site Calibration not easily documented
- Site Calibration not usually interchangeable with other GNSS manufacturers
- Site Calibration not usable in conjunction with GIS software

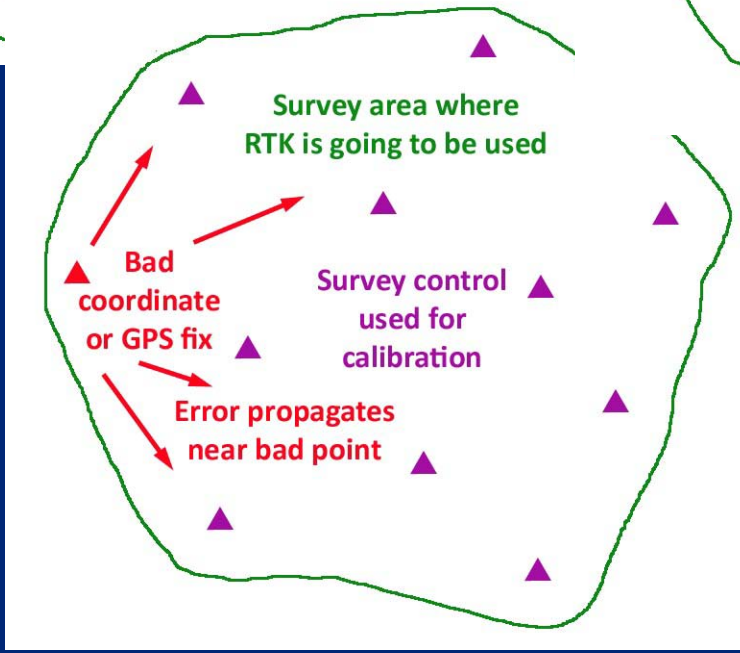
Site Calibration geometry



Good geometry



Bad geometry



Corrupt geometry

Local Transverse Mercator (LTM) – Design Principles

1. Limits of LTM coverage (to maintain > 1:20,000 precision)

   East-West limits vary from
   6,000 m at the MGA94 Zone boundary to
   60,000m near the MGA94 Zone central meridian
   > 300 m elevation difference will exceed 1:20,000

2. Choose the LTM Origin

   Close to centre of project
   LTM origin can be a survey station, but not essential
   Height should be mean of area for reference SF calculation

3. Choose LTM Origin Coordinates

   Small magnitude & no negative coordinates
   Easting range outside Northing range for survey area
   (to prevent confusion if E and N are transposed)

Building your own LTM

LTM Origin

Station 1034

MGA94 Zone 55

E 350789.249

N 5837027.732

AHD 247.257

LTM Coords

E 1789.249

N 7027.732

MGA conversion — copy row 20 down for more calculations

Hemisphere -1 (-1=Southern, 1=Northern) — e2 0.0066943800

QUICKCLOSE

a = 6378137.000 — 1/f = 298.25722210 — k_0 = 0.9996000 — GRS80 Ellipsoid

Version 1.2 10th January 2011 (Freeware, *QUICKCLOSE* Software - PO Box 1364 Carlton VIC 3053 AUSTRALIA)

MGA Zone	Easting	Northing	Ellipsoid Height	Latitude (decimal °) (negative in Southern Hem.)	Longitude (decimal °) (negative in Western Hem.)	Ellipsoid Height	GDA94 Latitude (Deg,Min,Sec)			GDA94 Longitude (Deg,Min,Sec)			Ellipsoid Height	MM	H t	Grid Convergence (decimal °)	Grid (Point) Scale Factor	Combined Height & Grid Scale Factor
55	350789.249	5837027.732	247.257	-37.6017429388	145.3096730411	247.257	-37	36	6.27458	145	18	34.82295	247.257	#	#	-1.0315758	0.9998742	0.9998354429
55	500000.000	10000000.000	0.000	0.0000000000	147.0000000000	0.000	0	0	0.00000	147	0	0.00000	0.000	#	#	0.0000000	0.9996000	0.9996000

Local Transverse Mercator (LTM) terms

$$\lambda_{LCM} = \lambda_{MGACM}$$

$$\phi_{LPO} = \phi_{MGAPO} = 0°$$

$$E_{LCM} = E_{LO} + \frac{500000 - E_{MO}}{F_M}$$

$$N_{LPO} = N_{LO} + \frac{10000000 - N_{MO}}{F_M}$$

$$k_{LCM} = \frac{0.9996}{F_M}$$

λ_{LCM}	is the Longitude of the LTM central meridian
λ_{MGACM}	is the Longitude of the MGA Zone central meridian
ϕ_{LPO}	is the Latitude of the LTM latitude origin (usually 0°)
ϕ_{MGAPO}	is the Latitude of the MGA latitude origin (0°)
E_{LCM}	is the LTM Easting of the MGA Central meridian
E_{LO}	is the LTM Easting of the local origin
E_{MO}	is the MGA Easting of the local origin
F_M	is the Combined Scale Factor (MGA and Sea level) at the height of the local origin
N_{LPO}	is the LTM Northing of the MGA Latitude origin (0°)
N_{LO}	is the LTM Northing of the local origin
N_{MO}	is the MGA Northing of the local origin
k_{LCM}	is the LTM scale factor at the MGA central meridian

LOCAL TRANSVERSE MERCATOR
(UTM OR MGA94 ALIGNED)
BUILDER

Enter data into blue/purple cells
parameters computed in orange cells

		Local Coordinate Origin		
	Zone	Easting	Northing	Elevation
UTM/MGA94 Coordinates	55	350789.249	5837027.732	247.257
User Defined Coords		1789.249	7027.732	
Easting Central Meridian	$E_{(LCM)}$	151024.558		
Northing at Latitude Origin Proj.	$N_{(LPO)}$	4170685.159		
Scale Factor of Central Meridian	$k_{(LCM)}$	0.9997645184		
Longitude of Central Meridian	$\lambda_{(CM)}$	147		

λ_{LCM} = λ_{MGACM} = 147° deg E (Zone 55)
ϕ_{LPO} = ϕ_{MGAPO} = 0°
E_{LO} = 1789.249
E_{MO} = 350789.249
F_M = 0.9998354429 (from spreadsheet 10 d.p.)
E_{LCM} = 151024.558 (formula)
N_{LO} = 7027.732
N_{MO} = 5837027.732
N_{LPO} = 4170685.159 (formula)
k_{LCM} = 0.9997645184 (formula) (10 d.p.)

Local Transverse Mercator (LTM) - Summary

- The scale factor (combined height and grid factor) is close to 1
- LTM bearings will be identical to those in the parent MGA projection (no swing or rotation)
- Coordinate magnitudes kept small to prevent confusion with MGA coordinates
- LTM parameters can be easily setup in GNSS RTK software (no calibration required)
- LTM parameters can be exchanged consistently between different manufacturers
- LTM parameters can also be setup easily in GIS software projection configurations. LTM ellipsoidal coordinates identical to GDA94.

Local Transverse Mercator (LTM) - Limitations

- An MGA aligned LTM cannot be used beyond 6 kilometres close to the MGA Zone boundary
- An LTM is not particularly suited to areas that have large extents in an East/West orientation or elevation differences greater than 300 metres

Next ….. An LTM in practice
Using GNSS to establish cadastral control