Background information on the Global Positioning System and handheld units

1 Purpose and scope

This document will help develop a basic understanding of handheld Global Positioning System (GPS) units and the methods they use to calculate a position. It also covers factors that may affect the accuracy of position calculations and methods to mitigate the effect of those factors.

2 Associated documents

Sampling design and preparation: Operating a basic handheld Global Positioning System unit for an investigation or compliance inspection

3 Introduction

Global Positioning System (GPS) receiver units are important tools for determining accurate locations for field sampling sites.

There are two main types of coordinate systems—spherical coordinates expressed as latitudes and longitudes (referred to as geographic coordinates) and projected coordinates (usually expressed in metres relative to the origin point of the projected plane). Geographic coordinate systems establish a position based on the earth's approximately spherical surface, whereas projected coordinate systems are a way of presenting the three dimensional (3D) data of the earth's surface on a two dimensional (2D) plane.

The World Geodetic System 1984 (WGS84) is a commonly used datum in GPS units world-wide. A large number of 'localised' datums also exist, for example the Geocentric Datum of Australia 1994 (GDA94). GPS units can convert the WGS84 position to other datums. Datums are typically expressed in decimal degrees or degrees minutes and seconds of arc.

The Universal Transverse Mercator (UTM) projection is one method used world-wide to project the earth's surface onto maps. A key feature of the UTM projection is that it creates sixty zones around the earth, each six degrees in width (Figure 1). An example of how UTM coordinates are written using eastings and northings, as well as what each section relates to is shown below (Example 1). The current UTM projection is based on the WGS84 datum. Older maps and digital spatial data (including GPS coordinates) may be based on other datum, resulting in some discrepancies with position.

Example 1:

UTM zone UTM band

55 J 0334900 E / 5600067 S

Easting (m) Northing (m)

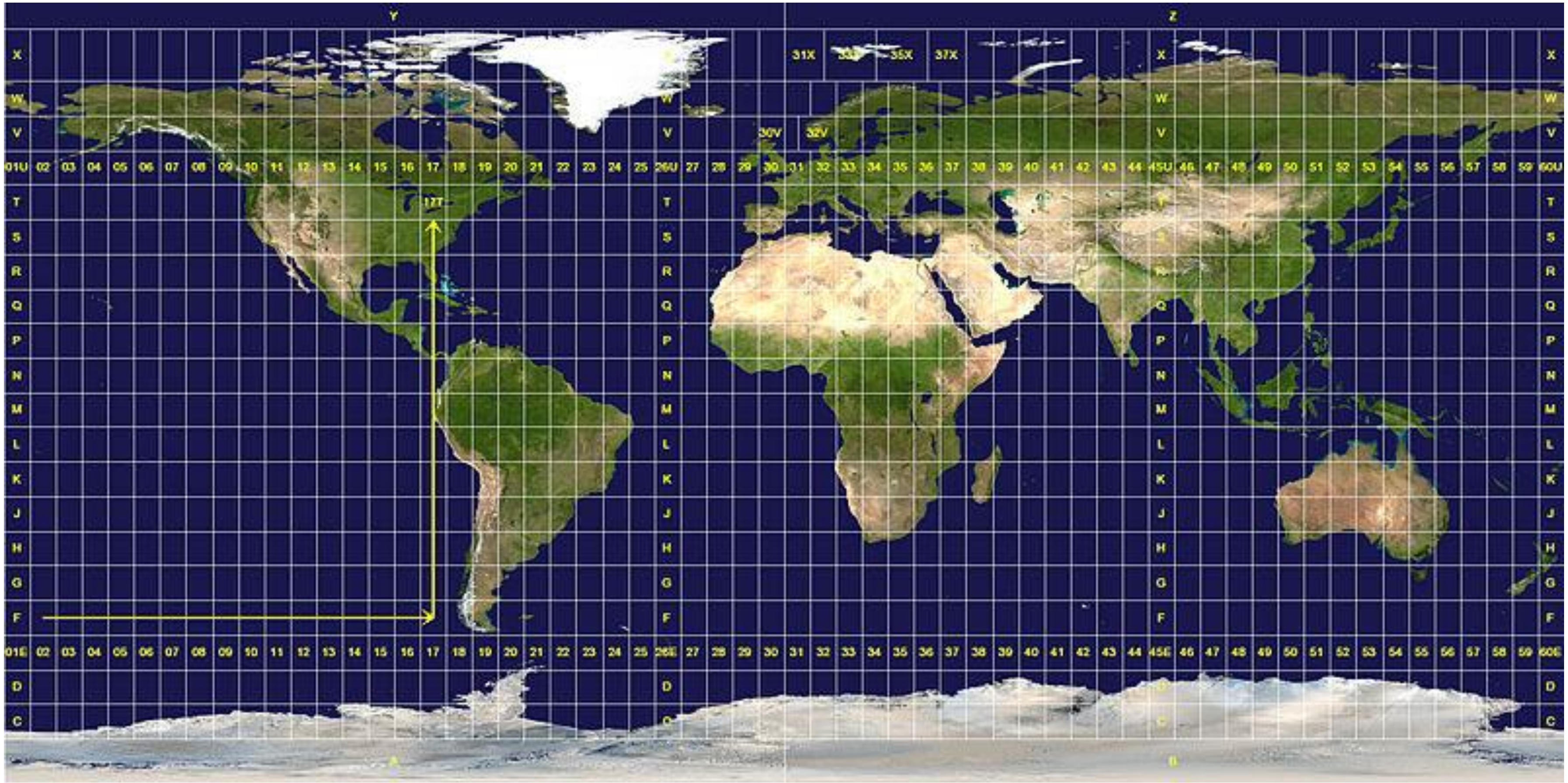

Figure 1: Universal Transverse Mercator (UTM) zones

4 How GPS receivers calculate positions

GPS satellites transmit a signal that includes the unique identifier for the satellite, its location in space and the time of the signal. This transmission is received by the GPS unit and used, in combination with signals from other satellites, to calculate the position of the GPS unit.

At least four satellites must be visible (above the horizon) to calculate a '3D position' (longitude, latitude, elevation). Generally, the greater the number of satellites used to calculate the position, the more accurate the calculated position is.

Most GPS units will indicate when it is able to calculate a 3D position or if it is still acquiring the satellites and either cannot provide a position or only provide a 2D position (latitude, longitude). It is recommended that you do not collect 2D positions because of the problem encountered with the altitude measurement. When you set the receiver to calculate 2D positions, you are replacing one satellite measurement (altitude) with a fixed measurement. If this altitude is incorrect, the latitude and longitude will also be incorrect. For example, if the fixed altitude is incorrect by 10 meters, the calculated horizontal measurements can be incorrect by 50 meters or more (Trimble Navigation Limited 2002).

The relative geometry of the satellites and the GPS unit plays an important part in the accuracy of the position solution. This effect is called Geometric Dilution of Precision (GDOP). GDOP refers to where the satellites are in relation to one another, and is a measure of the quality of the satellite configuration. It can magnify or lessen other GPS errors. In general, the wider the angle between satellites, the better the measurement.

5 GPS precision, accuracy and reliability

A GPS unit can produce precise, accurate and reliable positional data. For the purpose of this document, the term accuracy is used to describe all three factors outlined above.

The accuracy of the GPS unit's position calculation can be affected by a number of factors. Many of these factors can be managed by the GPS unit itself or through the users understanding of the operation of the GPS unit and their surroundings.

Most units display an 'accuracy' reading which partly indicates the degree of precision of the position calculation (Figure 2), but may not account for all sources of interference with the signals and so should be treated with caution. Generally, a basic handheld GPS unit will be relatively accurate and most modern units can calculate a 'horizontal' position to within 10m and a 'vertical' position (elevation) to within 50–100m.

Interferences to be aware of are:

- Vegetation canopy cover or nearby landscape features will affect the number of satellites being received by the GPS unit. The most accurate readings will generally be received when a clear view of the sky is available and signals are not at risk of interference.
- If the GPS unit is being used whilst stationary, it can (subject to other factors) provide a more accurate position calculation than if moving. Using the unit whilst completely stationary allows an improvement in the calculation through the unit being able to average its calculations over time.
- Holding a GPS unit close to the operator's body or within a vehicle is likely to affect 'line of sight' with satellites and affect the accuracy of the GPS reading.
- When a satellite is 'low' in the horizon, the signal must travel a longer distance through the ionosphere and troposphere. This could result in a weaker signal and greater interference. Most modern GPS units will only detect satellites that are greater than 15 degrees above the horizon to minimise these effects.
- The quality and position of the GPS unit's antennae can also be a factor. Many units can be fitted with an external (vehicle or high mounted) antennae to improve the ability of the unit to receive signals without interference.
- The signal-to-noise ratio (SNR) of a satellite is a measure of the signal strength or the amount of information content relative to the signal's noise. Noise refers to the degree of interference to the signal and can typically be caused by a weakening of the signal due to:

   - The signal having penetrated a barrier (e.g. vegetation cover)
   - Reflection of the signal off another surface, called multipath, such as buildings or even the operators body. Normally, accuracy errors from this source is less than 3m
   - The position of the satellite low in the horizon
   - Antennae quality.
- Unintentional radio frequency interference can be caused by TV transmitter signals, radar signals, and CB radio transmissions. Intentional interference is also possible. Radio frequency interference can cause complete loss of tracking, distorted signals, and incomplete data.

Table 1 outlines potential sources of GPS error.

Note: Ensure the GPS unit you use, and its ability to accurately calculate a position, matches the data quality or accuracy standard you require for the activity or task you are completing. The need for highly accurate positional data (e.g. to determine the exact cadastral boundaries of a property) will require specific equipment and appropriately qualified operators of that equipment.

Table 1: GPS error budget (taken from http://www.montana.edu/gps/understd.html)

Error source	Potential error	Typical error
Ionosphere	5.0 meters	0.4 meters
Troposphere	0.5 meters	0.2 meters
Ephemeris data	2.5 meters	0 meters
Satellite clock drift	1.5 meters	0 meters
Multipath	0.6 meters	0.6 meters
Measurement noise	0.3 meters	0.3 meters
Total	~ 15 meters	~ 10 meters

Figure 2: Most GPS units display an 'accuracy' reading

6 References and additional reading

Garmin Corporation 2000, *GPS Guide for Beginners,* viewed 23 June 2002.

Trimble Navigation Limited 2010, *Trimble GPS Tutorial,* viewed 23 June 2002.

Trimble Navigation Limited 2002, *Mapping Systems: General reference*, viewed 9 September 2015, p62.

USGS 2006, *Map Projections.* viewed 14 August 2015.

ICSM 2 April 2001, *What is the difference between WGS84 and GDA94?*, viewed 8 September 2015.