

Oakland County GPS Standards

1.0 Introduction

The Mobile Computing Strategic Plan document issued by the Department of Information Technology in August 2002 indicates that there are several departments within Oakland County government that have a need for GPS. This document outlines Geospatial Positioning Accuracy standards for the use of GPS by Oakland County departments. These standards assist Oakland County's Department of Information Technology in establishing guidelines for the acquisition and use of GPS hardware and associated software. These standards should be consulted when developing business workflows that incorporate horizontal and vertical coordinate values obtained by GPS receivers.

2.0 Scope

The standards outlined in this document should be utilized by all county departments and may be used by Oakland County CVTs if they so choose. This will ensure consistent understanding among GIS/GPS stakeholders within Oakland County.

GPS hardware and GPS interface software are considered independently of one another in this document. In many cases, different GPS hardware devices may be connected to the same field data collection device which implements a GPS interface. This emphasizes the need for standardization.

3.0 Purpose

The purpose of this document is to provide a description and classification of the range of accuracies that can be obtained from GPS technology to assist County Departments and CVTs in selecting the most appropriate GPS technology for a given application. For the purposes of this document, three levels of accuracy have been categorized: infrastructure grade, survey grade, and navigation grade.

As a result of the County's GPS selection process, specific hardware and software configurations for each category of accuracy will be defined. Combining the standard with the available procurement information will provide guidance on the specific receivers, software, and hardware that will support a defined application.

Oakland County maintains an enterprise GIS that is available to all county departments and CVTs. Defining standards for GPS data will ensure that GPS data will integrate with existing IT systems supported by Oakland County's Department of Information Technology (both GIS and non-GIS systems).

This standard also ensures that data created by Oakland County via GPS technology conforms to applicable positional accuracy standards (FGDC, ISO, NSSDA, etc.)

These standards will provide guidelines that will assist Oakland County GPS stakeholders with the selection of third-party vendors to provide GPS related products and services (training, device configuration, and technical support).

These standards will serve as a reference that can be used in the evaluation and reporting of the positional accuracy of spatial data captured by GPS receivers.

4.0 Definitions

Accuracy – Degree of conformity with a standard. Accuracy relates to the quality of a result and is distinguished from precision which relates to the quality of the operation by which the result is obtained.

Almanac – A data file that contains orbit information on all satellites, clock corrections, and atmospheric delay parameters. It is transmitted by a GPS satellite to a GPS receiver, where it facilitates rapid satellite vehicle acquisition within GPS receivers. Almanac data must be acquired before GPS navigation can begin.

Azimuth – The directional bearing on a 360-degree circle which is measured clockwise from north

Carrier Phase – The difference between the carrier signal generated by the internal oscillator of a receiver and the carrier signal coming from the satellite.

C/A code – The standard (Course/Acquisition) GPS code. A sequence of 1023 pseudo-random, binary, biphasic modulations on the GPS carrier at a chip rate of 1.023 MHz. Also known as the "civilian code."

Channel – A channel of a GPS receiver consists of the circuitry necessary to received the signal from a single GPS satellite.

Confidence Region – A rigorous measure of accuracy representing the region within which the true value should be found a certain percentage of the time. Usually the 95% figure is used. Confidence regions can be 1-D (confidence limits), 2-D (confidence ellipse), or 3-D (confidence ellipsoid).

CORS (Continuously Operating Reference Station) – Provide Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories.

Datum – A set of parameters and control points used to accurately define the three-dimensional shape of the Earth (e.g., as a spheroid). A math model which depicts the surface of the earth. The datum is the basis for a planar coordinate system.

Ellipsoid – A mathematical model of the earth formed by rotating an ellipse around its minor axis. For ellipsoids which model the earth, the minor axis is the polar axis, and the major axis is the equatorial axis. An ellipsoid is completely defined by specifying the lengths of both axes, or by specifying the length of the major axis and the flattening.

Ephemeris – The current satellite position predictions that are transmitted in the NAVDATA message.

Geodetic Datum – A mathematical model designed to fit part or all of the geoid, defined by the relationship between an ellipsoid and a point on the topographic surface established as the origin of a datum. World geodetic datums are typically defined by the size and shape of an ellipsoid and the location of the center of the ellipsoid with respect to the center of the earth.

Geoid – The surface of gravitational equipotential which closely approximates mean sea level.

GPS (Global Positioning System) – Developed for the military for navigation and surveying, the GPS relies on satellites and ground stations for precise determination of location on the face of the earth.

L1 – The primary L-band carrier used by GPS satellites to transmit satellite data. The frequency is 1575.42 MHz. It is modulated by C/A Code, P-Code and a 50 bit/second navigation message.

L2 – The secondary L-band carrier used by GPS Satellites to transmit satellite data. The frequency is 1227.6MHz. It is modulated by P-Code and a 50 bit/second navigation message.

Multipath – Errors caused by the interference of a signal that has reached the receiver antenna by two or more different paths. Usually caused by one path being bounced or reflected.

NAVDATA – The navigation message broadcast by each GPS satellite on both the L1 and L2 beacons. This message contains system time, clock correction parameters, ionospheric delay model parameters, and the vehicle's ephemeris and health. A GPS receiver can use this information to process GPS signals and thus obtain user position and velocity.

NAVSTAR – The name given to GPS satellites. NAVSTAR is an acronym formed from NAVigation Satellite Timing and Ranging.

P-Code – The precise code transmitted by the GPS satellites. Each satellite has a unique code that is modulated on to both the L1 and L2 carrier waves. The P-code is replaced by a Y-code when Anti-Spoofing is active.

Pseudorandom Noise or Number (PRN) – A signal that carries a code that appears to be randomly distributed like noise, but can be exactly reproduced. PRN codes have a low auto-correlation value for all delays or lags, except when they are exactly coincident. Each NAVSTAR satellite has its own unique PRN code.

PDOP (Position Dilution of Precision) – Measure of the geometrical strength of the GPS satellite configuration.

Precision – A quality associated with the refinement of instruments and measurements, indicated by the degree of uniformity and repeatability of observations.

Root mean square error – A one-dimensional measure of accuracy representing the limits (plus or minus) within which the true value lies 68% of the time. Twice-distance Root Mean Square is the horizontal measure of accuracy representing the radius of a circle within which the true value lies at least 95% of the time.

RTCM – Radio Technical Commission for Maritime Services. A commission established to define a differential data link for real-time differential correction of roving GPS receivers. There are two types of RTCM differential correction messages.

Selective Availability – The random error, which the government can intentionally add to GPS signals, so that their accuracy for civilian use is degraded.

Signal-to-Noise Ratio (SNR) – A measure of the strength of a satellite signal. SNR ranges from 0 to around 35. Higher-elevation satellites have SNR's in the high teens to low 20's. SNR's lower than 5 are considered unusable. The ratio of the amplitude of the desired signal to the amplitude of noise signals at a given point in time. SNR is expressed as 20 times the logarithm of the amplitude ratio, or 10 times the logarithm of the power ratio. SNR is usually expressed in decibels and in terms of peak values for impulse noise and root-mean-square values for random noise. In defining or specifying the SNR, both the signal and noise should be characterized, *e.g.*, peak-signal-to-peak-noise ratio, in order to avoid ambiguity.

Spatial Decorrelation – The gradual increase in error as the base and rover separation increases. This error is a result of the fact that the primary assumption of DGPS (that the errors at the base are identical to the errors at the rover) is not 100% true.

SV – Satellite Vehicle or Space Vehicle.

Tropospheric Delay – A wave propagating through the ionosphere experiences delay. The delay depends on electron content and affects carrier signals. Group Delay depends on

dispersion in the troposphere as well, and affects signal modulation (codes). The phase and group delay are of the same magnitude but opposite sign.

UTC – Universal Time Coordinate. Local solar mean time at Greenwich Meridian. A uniform atomic time system maintained by the US Naval Observatory and kept very close to UT2 by offsets.

WAAS (Wide Area Augmentation System) – A system of satellites and ground stations that provide GPS signal corrections for better position accuracy.

Waypoint – Designated locations or landmarks whose coordinates are known.

WGS84 (World Geodetic System 1984) – The primary map datum used by GPS.

5.0 GPS Receiver Parameters

GPS receivers must be calibrated and configured prior to their use. The following parameters are considered minimum requirements for positions captured in the field with GPS receivers.

- ❖ Minimum number of positions – 30
- ❖ Occupation time – This time will be dependent on the time necessary to capture 30 positions and may vary by receiver, time of day, and time of year.
- ❖ PDOP mask – max 6 (infrastructure grade); max 4 (survey grade)
- ❖ SNR mask – min 4
- ❖ Elevation mask – 15 degrees
- ❖ Real-time DGPS source – nearest signal, strongest signal (for receivers utilizing real-time radio beacons).

6.0 Positional Accuracy Standards

Estimates of positional accuracy should use the root-mean-square error (RMSE) method. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points (FGDC NSSDA).

Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported

accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product (FGDC NSSDA).

- ❖ Infrastructure Grade Accuracy – This category deals with GPS data collection for features in the built and natural environment. This grade may also be called resource grade.
- ❖ Survey Grade Accuracy – This category deals with GPS data collection for features of survey quality.
- ❖ Navigation Grade Accuracy – This category deals with GPS data collection for mobile applications such as Automatic Vehicle Location systems.

Accuracy Category	Horizontal Accuracy – 95% Confidence Level (less than or equal to)
Infrastructure Grade	1 meter
Survey Grade	1 centimeter
Navigation Grade	10 meter

A good rule of thumb regarding vertical accuracy is to expect it to be somewhere near half the horizontal accuracy. However most manufacturers do not publish a vertical accuracy specification for these instruments, hence the 'rule-of-thumb' of halving the horizontal accuracy.

7.0 GPS Hardware Interface Standards

GPS user interfaces that are used by stakeholders that are supported by Oakland County's Department of Information Technology must conform to Oakland County's standard technical environment (Windows NT/XP, Windows Pocket PC, ArcGIS, network compatible for GPS receivers that require it, etc.).

GPS software interface must allow for configuration of the parameters noted in section 6.0. The interface must provide the capability of viewing the status of dynamic parameters that fluctuate during GPS data collection.

Acceptable GPS software interfaces will allow for import and visualization of GIS layers in Oakland County's standard format.

8.0 Metadata

Static subtype values are assigned to GPS receiver models that meet Oakland County's standards. Domain attribute values for coordinate capture method (DG-differential GPS, SG-static GPS, KG-kinematic GPS, CG-coarse GPS, etc.) and coordinate accuracy (1M-

one meter, 3M-three meter, 10M-ten meter, etc.) will be reported in the metadata. These values will be used to populate positional accuracy values in GIS and/or non-GIS system tables. Standardization of these values across the County will help to ensure collective understanding of GPS data accuracy for GIS users.

Additional metadata elements relating to the date and time of position capture as well as the agency doing the collection will be included. Specific receiver information and receiver calibration or configuration information will be automatically populated as a part of the metadata.

All coordinates will be expressed in Michigan State Plane Coordinates, NAD 83 South Zone International Feet.