Standards and Guidelines

For

CADASTRAL SURVEYS

Using

Global Positioning System Methods

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by

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Forward

These Standards and Guidelines provide guidance to the Government cadastral surveyor and other land surveyors in the use of Global Positioning System (GPS) technology to perform Public Land Survey System (PLSS) surveys of the Public Lands of the United States of America.

Many sources were consulted during the preparation of this document. These sources included other GPS survey standards and guidelines, technical reports and manuals. Opinions and reviews were also sought from Public and private Professional Land Surveyors who use GPS for boundary and Cadastral Surveys.

The static and fast static survey procedures in these guidelines follow long est[illegible] and well-documented industry and government survey practices. However, guidelines [illegible]eal-tim[illegible]c surveys of all types are in the early stages of development.

Manufacturer's technical manuals describe real-time kinem[illegible]ic GPS su[illegible]eys as a[illegible]hic su[illegible]eying method for small areas. It was not intended for surveying l[illegible] land b[illegible]ndaries or fo[illegible]t areas. Therefore, the guidelines for performing land surveys usin[illegible]e kinematic GPS t[illegible]es require greater observational and occupational redundancies and ch[illegible] specified by the manufacturers.

These standards and guidelines do not require that Cadastra[illegible] Surv[illegible]rformed to the higher accuracy and methodology requirements of geodetic control surveys. The[illegible]ended to provide sufficient observational and occupational redundancy to detect blunders and qu[illegible] demonstrate the stated accuracy of a survey has been achieved.

Cadastral Surveys are an important part of the [illegible]ational S[illegible] Infras[illegible]ucture. The accuracy reporting requirements of this document are in acco[illegible]ance wit[illegible]ac[illegible]ng requirements of the Federal Geographic Data Committee's "Geospatial [illegible]ositioning [illegible]ccura[illegible]ards", July 1997.

Disclaimer Statement

This document is intended onl[illegible]fo[illegible]e purpos[illegible]g the user with guidelines for planning, execution, a[illegible]classificatio[illegible]S surveys[illegible] using GPS carrier phase methodology.

Note: Itali[illegible]s in bold [illegible] ***independent occupation,*** indicate that a definition for that word appears in A[illegible] Definitio[illegible]

Part One

Standards for Positional Accuracy

The following standards are for GPS technology only and shall be used to define the minimally acceptable levels of differential relative positional accuracy required of a Government cadastral survey.

TABLE ONE: **Local Accuracy Standards**

Local Accuracy	95% Confidence Circle	Application
0.050 meters (m)	Less than 0.050 (m)	*Cadastral Project Control*
0.100 meters (m)	Less than 0.100 (m)	*Cadastral Measurements*

Local Accuracy is an average measure (e.g. mean, median, etc.) of the relative [illegible] of the coordinates for a point with respect to other adjacent points at the 95% confidence level.

TABLE TWO: **Network Accuracy Standards**

Network Accuracy	95% Confidence Circle	Application
0.100 meters (m)	Less than [illegible]	*Cadastral Project Control*
0.200 meters (m)	Less than [illegible]	*Cadastral Measurements*

The ***Network Accuracy*** of all Cadastral Measurements should be reported per the Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards to show the relationship of the cadastral survey relative to the National Spatial Reference System.

A least squares adjustment or other multiple baseline data analysis is performed to produce a weighted mean average to verify the required level of positional accuracy has been achieved.

Part Two

Guidelines

The guidelines outlined in this document consist of field data acquisition methods, field survey operations and procedures, data processing and analysis methodologies, and documentation. The use of these guidelines and the manufacturer's specifications provide a means for the surveyor to evaluate the survey and to verify the specified accuracy standard has been achieved.

These guidelines are designed to ensure a survey performed with GPS technology is repeatable, legally defensible and referenced to the ***National Spatial Reference System (NSRS)*** by achieving the following:

Elimination or reduction of known and potential systematic error sources.

Occupational (station) and observational (baseline) redundancy to clearly demonstrate the stated accuracy.

Baseline processing, data adjustment and data analysis to clearly demonstrate the stated accuracy.

Documentation demonstrating verification of [illegible].

Compliance with the Bureau of Land Management <u>Manual of Instructions for the Survey of the Public Lands of the United States, 1973</u> and state law.

GPS survey guidelines continually evolve with the advancements in equipment and techniques. Changes to these guidelines are expected as these advancements occur. The size, scope and site conditions of a project may also require variations from these guidelines.

Any variations from these guidelines should be designed to meet the above criteria and to achieve the accuracy standard of the survey as required by this document. All variations shall be documented in the project report.

Section One

Field Data Acquisition Methods

A variety of GPS field data acquisition methods may be used for ***Cadastral Measurements*** and ***Cadastral Project Control***.

<u>Static Positioning:</u>

Static positioning typically uses a network or multiple baseline approach for positioning. It may involve multiple receivers, multiple baselines, multiple observational redundancies and multiple sessions. A least squares adjustment of the observations is required. This method provides the highest accuracy achievable and requires the longest observation times.

Static positioning is primarily used for ties to the National Spatial Reference System (NSRS) when observing Cadastral Project Control. This method may also be used for the Cadastral Measurement portion of a cadastral survey.

<u>Fast-Static Positioning:</u>

This method requires shorter occupation times (i.e. 5 to 20+ minutes) than static positioning and may use a radial baseline technique, network technique, or a combination of the two. Fast static requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. Fast-static positioning may be used for observing both the Cadastral Project Control and the Cadastral Measurements of a cadastral survey.

Post-Processed Kinematic (PPK) Positioning:

Post processed kinematic survey methods provide the surveyor with a technique for high production Cadastral Measurements and can be used in areas with minimal obstructions of the satellites. PPK uses significantly reduced observation times compared to static or fast-static observations. This method requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. PPK positioning is used for observing the Cadastral Measurements of a cadastral survey.

Real-time Kinematic (RTK) Positioning:

Real-time kinematic positioning is similar to a PPK or single station radial survey. RTK does not require post-processing of the data to obtain a position solution. This allows for real-time surveying in the field. This method allows the surveyor to make corner moves (stake out) similar to total station/data collector methods. RTK positioning is used for the Cadastral Measurement portion of a Cadastral Survey.

Real-time surveying technology may utilize dual-frequency (L1/L2) techniques for initialization, but the subsequent RTK survey is accomplished using the L1 carrier phase frequency. Therefore, all RTK surveys are currently subject to the limitations of the L1 frequency.

NOTE: Operations under a forest canopy using PPK or RTK methods are not recommended. However, these methods are acceptable if they result in a solution, which meets the survey standards. The surveyor must make an informed decision when choosing the appropriate methodology to be used in a particular project area. For survey projects in a forest canopy environment with minimal sky visibility, static or fast-static GPS methods or even conventional survey methods should be considered instead of using RTK or PPK.

Section Two

Field Survey Operations and Procedures

Field survey operations should be performed using the manufacturer's recommended receiver settings and observation times. Operations under adverse conditions, such as under a forest canopy, may require longer observation times than specified by the manufacturer.

Preset fixed height antenna tripods/bipods should be used for all rover GPS observations.

All plumbing/centering equipment should be periodically checked for proper adjustment.

The following topics are recommended procedures when using GPS measurement techniques for Cadastral Surveys.

Cadastral Project Control

Cadastral Project Control is the network of the GPS stations, tied to the NSRS, which is surveyed to control all subsequent GPS Cadastral Measurements.

A Cadastral Project Control network shall be established by either static or fast-static survey methods.

The Cadastral Project Control network may be established at the same time the Cadastral Measurements are made. However, the points and resulting baseline vectors used in the Cadastral Project Control network shall be processed to derive the baseline solutions and be adjusted by least squares independently of the observed Cadastral Measurements.

The Cadastral Project Control network is designed to meet the following purposes:

Provides a framework to reference the survey to a datum, a mapping projection, and the NSRS.

Supports registration of the Cadastral Measurements into the ***Geographic Coordinate Data Base (GCDB)***.

Serves as the basis for all subsequent GPS Cadastral Measurements.

Allows for reporting of the Network Accuracy for the Cadastral Measurements [illegible] Geospatial Positioning Accuracy Standards.

A well-designed Cadastral Project Control network w[illegible] surveyor more flexibility for using fast static, kinematic, and RTK survey methods for the [illegible] Measurement portion of a survey. It provides an adequate amount of referen[illegible] (bas[illegible] locations, ties the Cadastral Measurement points together, allows for expanding area of th[illegible] and provides accurate checks throughout survey project.

The number of stations in the Cadastral [illegible] network depends upon factors such as project size, topography, positioning [illegible]thod use[illegible]s. A minimum of two or more Cadastral Project Control stations s[illegible]uld be es[illegible]blis[illegible]erence for the Cadastral Measurements.

All Cadastral Project Control [illegible]tworks sh[illegible]ld be refe[illegible]nced (tied) to at least two High Accuracy Reference Network (HARN [illegible]ations/ H[illegible] Precision [illegible]eodetic Network (HPGN) or Continuous Operating Reference Stat[illegible] (CORS) [illegible]e NS[illegible]

In [illegible]sence of [illegible]GN or CO[illegible]ions, other GPS control stations which are [illegible] to the N[illegible]ublished by or available through other Federal, state, or local ag[illegible] be used [illegible] of such stations shall be evaluated by the surveyor regarding the relatio[illegible]e NSRS [illegible]lusion into the Cadastral Project Control network and prior to any Cad[illegible]surement[illegible]ing.

[illegible]e current natio[illegible]ce datum is the North American datum of 1983 (NAD83) of 1986. All control and projec[illegible]ation should be referenced to the most current epoch of NAD 83 for example: Wyomin[illegible] N[illegible]D 1983 (1993).

A[illegible]adastral Project Co[illegible]rol networks shall conform to the following:

Be referen[illegible] to two or more NSRS or other published horizontal control stations, located in two [illegible]adrants, relative to the cadastral project area.

[illegible]oints are established by two or more ***independent baselines***.

Contain loops of a minimum of three baselines.

Baselines have a fixed integer double difference solution or adhere to the manufacturer's specifications for baseline lengths exceeding the fixed solution criteria.

Any station pair used as azimuth or bearing reference for use with conventional survey measurements during the course of a cadastral survey should be included in a network or measured with a minimum of two independent vectors.

All stations in the cadastral project control network shall have two or more ***independent occupations***.

The Cadastral Project Control network must be a geometrically closed figure; therefore, single radial (spur) lines or side shots to a point are not acceptable.

Cadastral Measurements

Cadastral Measurements are the measurements used to define the location of Public Land Survey System (PLSS) corners and boundaries. Cadastral Measurements are referenced to the Cadastral Project Control coordinates or by direct ties to the NSRS.

All Cadastral Measurement observations, except RTK, shall adhere to the following:

Be constrained to two or more Cadastral Project or NSRS stations which are located in two or more quadrants relative to the cadastral project area.

Points are established by two or more independent baselines.

Contain loops of a minimum of three independent baselines.

Baselines have a fixed integer double difference solution or adhere to the manufacturer's specifications for baseline lengths exceeding the fixed solution criteria.

Any station pair used as azimuth or bearing reference for use with conventional survey measurements during the course of a cadastral survey should be included in a network or measured with a minimum of two independent vectors.

All stations in the Cadastral Measurements shall have two or more independent occupations.

Single radial (spur) lines or side shots to a point are not acceptable.

Static Survey Methods

When using static methods as the sole measurement method for Cadastral Measurements, then the Cadastral Project Control and the Cadastral Measurements are considered to be the same. There is no need to establish a separate Cadastral Control Network. The ties the NSRS should be processed and adjusted independently of the Cadastral Measurements.

Static survey methods for Cadastral Measurements, uses a network or a multiple baseline observational scheme.

Fast-static Survey Methods

When using Fast-static methods as the sole measurement method for Cadastral Measurement, then the Cadastral Project Control and the Cadastral Measurements are separate.

One method uses one or more reference (base) receivers usually two located in two or more different quadrants and one or more rover receivers with adjustable fixed height antenna tripods/bipods for Cadastral Measurements.

Another method uses two or more receivers in traverse or leapfrog observational scheme.

Post-Processed Kinematic (PPK) Survey Methods

When using PPK survey methods, which include stop and go, continuous, leapfrog and other observation schemes as the sole measurement method for Cadastral Measurements, then the Cadastral Measurements and Cadastral Project Control are separate

This method uses one or more reference (base) receivers usually two located in two or more different quadrants and one or more rover receivers for Cadastral Measurements.

Real-Time Kinematic (RTK) Survey Methods

When using RTK survey methods, as the sole measurement method for Cadastral Measurement, then the Cadastral Project Control and the Cadastral Measurements are separate.

RTK uses a radial style survey scheme with one or more reference (base) receiver and one or more rover receivers for Cadastral Measurements.

The radial nature of RTK requires additional redundant measurements be made as part of the field survey operations and procedures as discussed in these guidelines.

There are four parts of an RTK survey which include:

System check

Corner measurements

RTK calibrations

Corner moves (stake-out)

RTK System Check

A RTK system check shall be made prior to any RTK Cadastral Measurements.

A RTK system check may also be made at any time during the course of each RTK survey session or at any time the base receiver and rover receiver(s) are setup and initialized per the manufacturer's recommended procedures.

This check is a measurement from the RTK base setup to another Cadastral Project Control station or a previously observed Cadastral Measurement point.

When observing these measurements, the rover will be set to manufacturer's specifications for ***duplicate point tolerance*** for the measurement of a known point and existing point name.

This check consists of re-observing a known position within the survey. The resulting observed position is then compared by inverse to the previously observed position for the known point. This inverse should be within the manufacturer's recommended values for duplicate point tolerance measurements.

This RTK system check is designed to check the following:

The correct reference base station is occupied.

The GPS antenna height is correctly measured and entered at the base and rover.

The receiver antennas are plumb over station at base and rover.

The base coordinates are in the correct datum and plane projections are correct.

The reference base stations or the remote stations have not been disturbed.

The radio-communication link is working.

The RTK system is initialized correctly.

RMS values are within manufacturer's limits.

<u>RTK Corner Measurements</u>

Corner measurements are usually made with RTK using one or more base and [illegible] rover receiver configurations.

RTK corner measurements shall be made after the [illegible] up check procedures have been completed.

Specified observation times for the highest level of accuracy [illegible] for corner measurements as per manufacturer's recommendations are [illegible]ended, (for [illegible], 180 seconds of time or when the horizontal (0.02m) and vertical ([illegible]sion has been met for a Trimble kinematic control point).

Under optimal conditions (clear sky, low RMS), deviation [illegible] the manufactures suggested times is appropriate, (for example, a corner may be observed using 30 seconds of time and 20 epochs of measurement data). However, observation times should be set to account for field conditions, measurement methods (i.e. Trimble "topo point" or "kinematic control point") and the type of measurement checks being performed.

Recommended method for RTK corner measurement:

[illegible] is to observe [illegible] unknown point two or more times with the same point name (e.g. 100[illegible] use a duplicate point tolerance measurement criteria of 2.5 cm. When observing these [illegible]ents, the [illegible] shall be dumped between observations.

Another [illegible] found corner location or temporary point (unknown position), two baselines measurements [illegible]M2) are stored to the data collector or receiver for a specified number of seconds or epochs [illegible] a specified level of precision, (for example, the time requirement for a Trimble kinematic [illegible] point) depending upon manufacturer's recommended procedures.

Observation time may be increased due to the constraints of on-the-fly (OTF) post-processing kinematic (i.e. [illegible]0+ sec) if the field data is post-processed as a check.

The antenna should be inverted to force a loss of satellite lock, in between the M1 and M2 [illegible]ents, to force the system to reinitialize. The point values resulting from the first baseline [illegible]rement is stored and labeled (e.g. 100700M1), and the point resulting from the second baseline measurement is stored and labeled (e.g. 100700M2)

A field check of the level of accuracy between the measurements may be done by an inverse between M1 and M2. The resulting inverse distance should be less than the Duplicate Point Tolerance of 2.5 cm.

Note: The ***Cadastral Measurement Tolerance*** of 8.6 cm is the maximum acceptable distance for

M1 – M2 inverse. It should be accepted only under extremely poor GPS conditions due to tree cover, multi-path, etc. This worst-case condition should only be encountered in the most marginal field conditions for RTK surveys.

The Cadastral Measurement Tolerance value of 8.6 cm is derived from standard error propagation relationships. It is based on the following formula, the square root of the sum of the squares of the Cadastral Measurement Tolerance (8.6 cm) and the maximum allowable error of the Cadastral Project Control (5cm) should approximately equal the maximum allowable err[illegible] budget of the Cadastral Measurements (10cm).

The baseline measurements (i.e. M1/M2) to the found corner locatio[illegible]porary points shall be verified by at least one of the following methods (i.e. s[illegible]ic, fast[illegible]K or RTK).

Perform a check measurement (M3) from the same [illegible]adastral Pro[illegible]tion at a ti[illegible]at least 15 minutes after the M1 and M2 measurement[illegible]re taken.

An example of one of the many possible observatio[illegible] is described belo[illegible]

Using RTK, make a new measurement (M3) to the un[illegible]t (e.g. 100700) from the same base receiver setup separated in time by a minimum [illegible]

Perform a check measurement (M3) from another Cadastral [illegible]ject Station taken either simultaneously with the M1 and M2 meas[illegible] or at lea[illegible]inutes after the M1/M2 measurements. An example of one of ma[illegible]servation s[illegible]emes is listed below:

Using PPK, FS or static, make a new [illegible]easure[illegible]kn own point (e.g. 100700) with the base receiver setup on anothe[illegible]adastral [illegible]ject C[illegible]ation operating simultaneously.

RTK [illegible]alibrations

In real-time surveying (RTS) to rel[illegible] GPS pos[illegible]ns meas[illegible]ed in terms of the World Geodetic System of 1984 (WGS-84) ellipsoid and [illegible]ates, to [illegible]rdinates, some type of a calibration is required. This calibr[illegible] may be do[illegible]eld in the [illegible]tors or it may be done in the office and uploaded to the data[illegible]

A calibration [illegible]to a lea[illegible]djustment, which establishes or refines a transformation of the WGS-84 coor[illegible]local No[illegible]ting, and Elevation (NEE) coordinates. This transformation consists of a da[illegible]rmation, [illegible]een the WGS-84 ellipsoid and the local ellipsoid, a mapping projection an[illegible]ertical a[illegible]stment.

The se[illegible]of derived WGS[illegible]nates must be homogeneous (all in terms of each other) for use in a calib[illegible]ion to establish the[illegible]nship between WGS-84 data collected by GPS receivers and local control po[illegible]ons, expressed as a[illegible]cal map grid with elevations above sea level. This relationship is defined by a s[illegible]s of mathematical tr[illegible]sformations.

[illegible]bration may be[illegible]minimum of one point up to twenty points depending upon the size of the project. [illegible]sing calib[illegible]ns, the manufacturer's recommendation should be followed.

T[illegible]of points staked out depends on the accuracy of the calibration. Always use known Project Cadastral Control and ties to the NSRS for this reason.

RTK Corner Moves (stakeout)

RTK technology allows the surveyor to make a corner move or stakeout from a known position to an unknown (calculated) position relative to the controlling corners for a PLSS survey or resurvey.

The system check should be done any time throughout the survey to detect for blunders and the initialization quality of the survey prior to making any RTK observation for Cadastral Measurements and prior to making any corner moves.

Note: Caution should be exercised when using grid coordinated for stakeout. It is important to insure the appropriate corrections for convergence, elevation and distance are accounted for relative to the rules of the PLSS.

To make a corner move using RTK the following is a recommended procedure:

Navigate to the calculated corner location (e.g. 14[illegible]0CP) using [illegible]tes. For exam[illegible]e, navigate "from" station number (100700) and "to" sta[illegible]n number (1[illegible]70[illegible]

Take a measurement (e.g. 140700M1), inverse betw[illegible]n M1 a[illegible] compare to th[illegible] position (e.g. 140700CP) and move the remaining distance [illegible]on to the true (calcu[illegible]) location as necessary. Repeat as required until satisfied you ar[illegible]sition then store M1 and overwrite previously stored point.

Force loss of satellite lock and initialization by inverting the [illegible]tenna. Reinitialize and take another measurement (e.g. 140700M2) and stor[illegible]

Inverse between the measured one (140[illegible]) [illegible]easure[illegible]40700M2). If the measured positions (M1 and M2) are within the [illegible]plicate [illegible]ce o[illegible]he calculated position then the initializations and measurements a[illegible] correct. [illegible]ote, [illegible]and M2 measurements are of a shorter duration (30 seconds).

Set the monument at the tru[illegible]orner locat[illegible]n.

Take a measurement on [illegible] set mon[illegible]nt (e.g[illegible]r 180 seconds) and store the position with a diff[illegible]ent name (e.g. [illegible]0[illegible]0). Optio[illegible]e receiver or data collector to store data for su[illegible]uent post-p[illegible].

As[illegible]inverse [illegible]tored position (e.g. 140700) to the calculated corner position to dete[illegible]et true co[illegible]n, next inverse to the controlling corners and check the bearing and dista[illegible]ure the c[illegible]cedures were followed. The established corner location should be withi[illegible]local sp[illegible]ccuracy standards required of the survey.

Section Three

Data Processing and Data Analysis

[illegible]ta processing (ba[illegible]ine solutions) and data analysis (least squares or weighted mean average) shall [illegible] the manufactur[illegible]s recommended procedures.

[illegible]e fixed integer solution is required for all cadastral measurements regardless of the p[illegible]nique used.

Project Control network shall be processed to derive the baseline solutions and be adjusted by least squares independently of the observed Cadastral Measurements.

When integrating GPS observations into conventional terrestrial survey procedures it is imperative the surveyor verify the following:

The State Plane or local plane horizontal scale factors, angular rotation factors, zone and units of measure are applied correctly.

The combined scale factors for elevation, to determine ground distance at project elevation or an average project elevation are applied correctly.

The appropriate datum has been used.

A check to insure no hidden transformation or double transformations of the data has occurred.

If using GPS with terrestrial data, then a check (e.g. measure the distance between two know points with an EDM) should be done to insure the computation of the [illegible] scale factors are correct. This is done to insure the ***ground distances*** [illegible] appropriate[illegible]

A check to insure the computation and reporting of basis of bearing are appr[illegible]

Section Fou[illegible]

Documentation[illegible]

The use of GPS surveying methods to establish geodetic Project [illegible] Control and/or Cadastral Measurements for survey and resurvey of Public La[illegible]onsidered [illegible]ce of Professional Land Surveying in all states. Therefore, all GPS surveyin[illegible] must be performed under responsible charge of a federally authorized Land Surveyor or a Professional [illegible]eyor licensed to practice Land Surveying in the applicable state.

A surveyor's narrative report shall be prepared and submitted to the project file by the surveyor in responsible charge as documentation of the successful completion of the land survey or cadastral survey project.

A surveyor's narrative report should include:

M[illegible]d Model [illegible] receiver, [illegible]na, and related equipment.

A p[illegible] generated [illegible] summary of all RTK field operations, including calibrations, duplica[illegible]easurem[illegible]

A pro[illegible]d report [illegible]garding the baseline processing results and the software and v[illegible]sion numbe[illegible]

A processing gen[illegible]eport regarding the Network adjustment results including a summary of covariance's, sta[illegible]ard deviation or RMS values and the software and version number used.

A network diag[illegible]m, true line diagram or map showing the network configuration as designed.

A list of th[illegible]ARN, CORS or reference stations used in the survey.

[illegible] of coordinates by station including the datum, geoid model, epoch, and measurement units used.

Local and Network Accuracies.

A GMM .LZH file for inclusion into GCDB.

Document any variations from these guidelines.

Reporting bearings and Distances:

A Basis of Bearing for a Government Cadastral Survey, when using GPS technology shall be expressed as "Geodetic Bearing or Azimuth". This bearing or azimuth shall be determined at the midpoint of the observed line as the "mean" between the Normal Section Forward Azimuth (NSFA) and the Normal Section Back Azimuth (NSBA) between points.

All ground distances shall be determined at elevation, except where the requirements are for sea level, using the appropriate geoid model to determine the geoid separation. For a cadastral survey, the height above the geoid and the orthometric height shall be considered the same.

Appendix A

DEFINITIONS

Cadastral Project Control is the network of the GPS baselines tied to the NSRS, which is surveyed to control all subsequent GPS Cadastral Measurements. The Project Control is adjusted independently of other cadastral measurements.

Cadastral Measurement Tolerance is the maximum acceptable di[illegible]r inverse between two measurements to the same point. This value is 8.6 cm. [illegible]n measu[illegible]are made within this tolerance is in an RTK survey the two observations [illegible] be recorde[illegible]e point num[illegible]er. These redundant measurements can then be include[illegible]n a least squares o[illegible]eline an[illegible]ysis. This worst-case condition should only be encounter[illegible]n the mo[illegible] marginal fi[illegible]or RTK surveys. These points should be noted in the RTK r[illegible]

The Cadastral Measurement Tolerance value of 8.6 c[illegible]ed from standard error propagation relationships. It is based on the following formula, the [illegible] of the sum of the squares of the Cadastral Measurement Tolerance (8.6 cm) and [illegible] max[illegible]wable error of the Cadastral Project Control (5cm) should approximately equal the max[illegible]wable error budget of the Cadastral Measurements (10cm).

Cadastral Measurements are the [illegible]asureme[illegible] def[illegible]e the location of ***Public Land Survey System (PLSS)*** corners a[illegible]d bounda[illegible]es. [illegible]Measurements are based on the Cadastral Project Control coordina[illegible]es or dire[illegible] ties to t[illegible]S.

Duplicate Point Toleran[illegible] [illegible] the ma[illegible]um dista[illegible]e in an RTK system setup check that two observations of the same [illegible]nt can di[illegible]y. It als[illegible]he desired distance in an RTK survey that two obs[illegible]vations of the [illegible]e point shou[illegible] and still be recorded as the same point for least sq[illegible] or multi-b[illegible]alysis. T[illegible]te point tolerance for these guidelines is 2.5 cm.

The [illegible]ic Coordi[illegible] Base (GCDB)** is a database containing geographic coordinates, and the[illegible]ed attribu[illegible] corners of the Public Land Survey System.

[illegible]ound distanc[illegible] [illegible]rizontal distance measured at the mean elevation between two points.

Independent (N[illegible]-Trivial Baseline): For each observing session there are n-1 independent baselines where [illegible] is the number of receivers collecting data simultaneously during a session.

[illegible]ndepen[illegible]t Occupation: Two or more independent occupations for the stations of a network are [illegible] to help detect instrument and operator errors. Operator errors include those caused by [illegible]nna centering and height offset blunders. When a station is occupied during two or more sessions, back-to-back, the antenna pole or tripod will be reset and plumbed between sessions to meet the criteria for an independent occupation.

Local Accuracy, as defined in Part 2, Standards for Geodetic Networks, FGDC Geospatial Positioning Accuracy Standards, is an average measure (e.g. mean, median, etc.) of the relative accuracies of the coordinates for a point with respect to other adjacent points at the 95% confidence level. For horizontal coordinate accuracy, the local accuracy is computed using an average of the radii of the 95% relative confidence circles between the point in question and other adjacent points. This indicates how accurately a point is positioned with respect to other adjacent points in the local network. Based upon computed relative accuracies, local accuracy provides practical information for users conducting local surveys between control monuments of known position. Local accuracy is dependent upon the positioning method used to establish a point. If very precis[illegible]nstruments and techniques are used, the relative and local accuracies related to the p[illegible]nt will [illegible] very good.

The reported Local Accuracy for cadastral survey purpos[illegible] will be [illegible] from the error ellipses generated by a least squares or other multiple baseline [illegible]stical ana[illegible] is fully constrained to the Cadastral Project Control.

National Spatial Reference System (NSRS) is def[illegible]n anaged by the Na[illegible] Geodetic Survey (NGS). It is a consistent national coordinate s[illegible] specifies latitude, longitude, height, scale, gravity, and orientation throughout the N[illegible]ll as how these values change with time. NSRS consists of the following compone[illegible]s:

The National CORS, a set of Global Positioning System Contin[illegible]rating Reference Stations meeting NOAA geodetic standards for install[illegible]ration, and [illegible]stribution;

A network of permanently marked p[illegible]nts in[illegible]e Fede[illegible] Base Network (FBN), the Cooperative Base Network (CBN), a[illegible] the User De[illegible]work (UDN); and

A set of accurate models de[illegible]cribing [illegible]namic [illegible]ysical processes affecting spatial measurements.

High Accuracy Reference N[illegible]rk or Hig[illegible] Precision G[illegible]odetic Network stations established by GPS observations.

Vert[illegible]al control mark[illegible] wh[illegible]n define e[illegible] are referenced to NGVD 29 or NAVD 88.

[illegible]orizonta[illegible]al marks established to define the NSRS.

NSR[illegible]s a highly [illegible] precise, and consistent geographic reference framework throu gh[illegible]nited Sta[illegible]ations or marks established by GPS or High order levels should b[illegible] GPS su[illegible]ojects

[illegible]etwork Accura[illegible]bsolute accuracy of the coordinates for a point at the 95% confidence level, with respe[illegible] defined reference system. Network accuracy can be computed for any positioning proje[illegible]hat is connected to the National Spatial Reference System (NSRS).

The network a[illegible]uracy of a control point is a number, expressed in centimeters, that represents the uncertainty in[illegible]e coordinates, at the 95% confidence level, of this control point with respects to the geodetic d[illegible]m. For NSRS network accuracy classification, the datum is expressed by the geodetic [illegible] the Continuously Operated Reference Site (CORS) supported by National Geodetic [illegible] (NGS). By this definition, the local and network accuracy values at CORS sites are [illegible]onsidered to be infinitesimal, i.e., to approach zero.

Network accuracy for cadastral survey reporting purposes will be computed from the error ellipses generated in a least squares adjustment fully constrained to CORS or HARN stations.

APPENDIX B

COMPUTATION OF ACCURACIES

The local accuracies of the PLSS corners are based upon the results of a least squares adjustment of the survey observations used to establish their positions. They can be comp[illegible] from elements of a covariance matrix of the adjusted parameters, where the kno[illegible] NSR[illegible] control coordinate values have been weighted using their one-sigma network accuraci[illegible]

95% Confidence Circle

The 95% confidence circle representing a local acc[illegible]cy can b[illegible] derived from [illegible] minor semi-axes of the standard relative ellipse between [illegible] points. The 95% [illegible]nce circle is closely approximated from the major (a) and mi[illegible]mi-axis parameters of the standard ellipse and a set of coefficients. For circular error ellip[illegible]rcle coincides with the ellipse. For elongated error ellipses, the radius of the circle will b[illegible] s[illegible]rter than the major semi-axis of the ellipse. The radius r of the 95% confidence cir[illegible] is app[illegible] by:

$r = K_p a$

Where

$K_p = 1.960790 + 0.004071 C + 0.$[illegible]$4276 C^2 +$ [illegible]$.371625$ [illegible]

$C = b/a$.

Note that th[illegible] coefficients in t[illegible] ab[illegible]ve expres[illegible]cific to the 95% confidence level, such that when the major s[illegible]axis of the [illegible] ellipse is [illegible] by the value of K_p, the radius of the 95% confidence circle is [illegible]irectly, a[illegible]er conversion is required.

Appendix C

References

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