C Calculations and Search Rules

This appendix outlines some of the calculations performed by the Survey Controller software, and discusses the database search rules that are used.

For more information on the concepts associated with Survey Controller calculations see Chapter 5, Coordinate Systems.

C.1 Transforming Between Coordinate Systems

Coordinate transformation provides parameters so that one set of coordinates can be represented in terms of another.

Figure 5-1 on page 5-8 shows a typical route for the conversion of measurements to grid coordinates using the Survey Controller software.

This section provides an overview of the management and application of coordinate transformations using the Survey Controller software. It describes how to apply a datum transformation and map projection, and horizontal and vertical adjustments. It also describes how to create a local plane projection.

With the Survey Controller, an ***in-field*** calibration process defines transformation parameters derived from a set of points. This set of points is coordinated in terms of two systems:

- WGS-84 Latitude, Longitude, Height (LLH) geodetic coordinates
- a local system with project-specific Northing, Easting, Elevation (NEE) grid coordinates

The Survey Controller software accepts measured WGS-84 Cartesian coordinates and converts them to a local planar grid system. Alternatively, key in local planar grid coordinates or upload them from an office product. The Survey Controller converts these to WGS-84 Cartesian coordinates for stakeout purposes.

For more information on the creation of a user-defined plane projection see page C-7. For more information on Geoid models see page C-12.

C.1.1 Transforming WGS-84 ECEF to WGS-84 LLH

When GPS signals are processed by a receiver, they yield Earth-Centered-Earth-Fixed (*X*, *Y*, *Z*) coordinates. It is then necessary to transform these coordinates to more meaningful geodetic coordinates (ϕ, λ, *H*).

Here ϕ represents the geodetic latitude, λ is the longitude, and *H* is the perpendicular height above the WGS-84 ellipsoid.

First we define:

$$e^2 = 2f - f^2 \quad (1)$$

$$N = \frac{r}{\sqrt{1 - e^2 \sin^2(\phi)}} \quad (2)$$

where *f* is the flattening value for the source ellipse and *r* is the semi-major axis.

The values of the ECEF coordinates are:

$$X = (N + H).\cos(\phi).\cos(\lambda) \quad (3)$$

$$Y = (N + H).\cos(\phi).\sin(\lambda) \quad (4)$$

$$Z = [N(1 - e^2) + H].\sin(\phi) \quad (5)$$

The inverse problem (that of transforming ECEF coordinates to ϕ, λ, and *H*) is solved by using an iterative procedure. The values of e^2 and *N* now use the destination ellipsoid flattening and semi-major axis values:

$$\phi = \tan^{-1}\left(\frac{Z}{\sqrt{X^2 + Y^2}}(1 - e^2)\right) \quad (6)$$

then iterate

$$\phi = \tan^{-1}\left(\frac{Z + e^2 N \sin(\phi)}{\sqrt{X^2 + Y^2}}\right) \qquad (7)$$

$$\lambda = \tan^{-1}\left(\frac{Y}{X}\right) \qquad (8)$$

if 45°S < ϕ < 45°N

$$H = \frac{\sqrt{X^2 - Y^2}}{\cos(\phi)} - N \qquad (9)$$

or if ϕ > 45°N or ϕ < 45°S

$$H = \frac{Z}{\sin(\phi)} - N(1 + e^2) \qquad (10)$$

C.1.2 Datum Transformation

A datum transformation provides the necessary parameters for converting from one geodetic coordinate system to another.

The Survey Controller software can apply a predefined three- or seven-parameter datum transformation. It can also calculate a three-parameter datum transformation given points coordinated in WGS-84 and local L'L'H'.

$$X = T + kRX' \tag{11}$$

where X' is a matrix of 3-D Cartesian ECEF coordinates or Cartesian local coordinates, *T* is a matrix of translation parameters, *k* is a scalar, and *R* is a rotation matrix. In most cases, X' is measured and *T*, *k*, and *R* are user-specified.

To calculate a three-parameter datum transformation, pairs of WGS-84 LLH and local L'L'H' coordinates are needed.

In the trivial one point case, the three translation parameters are just the vector components of the ECEF vector that connect the ECEF pair derived from the WGS-84 LLH and the local L'L'H'.

In the non-trivial case, the translation parameters are the vector components of the average vector. This is represented as:

$$AX + W = 0 \tag{12}$$

where the solution

$$X = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} \qquad (13)$$

and

$$W = \begin{bmatrix} X_1 - X'_1 \\ Y_1 - Y'_1 \\ Z_1 - Z'_1 \\ X_2 - X'_2 \\ Y_2 - Y'_2 \\ Z_2 - Z'_2 \\ : \end{bmatrix} \qquad (14)$$

where X_n is the value of the ECEF coordinate derived from the local L'L'H' of the *n*th 3-D point in the list, and X'_n is the X value of the ECEF coordinate derived from the WGS-84 LLH of the *n*th 3-D point and

$$A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ & : & \end{bmatrix} \qquad (15)$$

is called the Molodensky matrix.

For more information, please refer to *GPS Satellite Surveying* by A. Leick (John Wiley & Sons, 1995).

C.1.3 Map Projection

A map projection defines the relationship between the local ellipsoidal surface (L’L’H’) and a plane. Generally, map projection parameters are based on a local conformal mapping model.

For more information about map projections, please refer to *Map Projections—A Working Manual* by J.P. Snyder (U.S. Geological Survey Professional Paper 1295, U.S. Government Printing Office, Washington, 1987).

For nearly all projection types used in the Survey Controller system, the height component of a projected coordinate is just the height above or below the datum at that point. For a plane projection, however, the definition includes an ellipsoidal height and a projected surface elevation at the origin point.

Plane projection

In the Survey Controller software, the definition of a plane projection consists of the following parameters:

- Origin point Latitude, Longitude, and Height
- Origin point Northing, Easting, and Elevation
- Scale factor
- Rotation
- Projection ellipsoid radius
- Projection ellipsoid flattening

Before the transformation from ellipsoidal coordinates to plane coordinates starts, the ellipsoidal height at the origin point is substituted for the point’s height. The conversion of the ellipsoid coordinates into ECEF coordinates can then take place.

The origin point is also coordinated in terms of the ECEF reference frame, so an ECEF vector can be computed between the origin point and the point in question. A projection scale and rotation relative to the origin point are applied to the dX,dY,dZ vector. This results in transformed dX',dY',dZ' values. This new vector is added to the NEE of the origin point. The elevation of the resultant NEE is adjusted by the residual between the point’s LLH height and the origin’s LLH height.

Note – When the Survey Controller software uses a geoid model based on the WGS-84 ellipsoid, it does not use the local height to grid elevation separation value that is defined in some projections.

C.1.4 Horizontal Adjustment

It may be necessary to minimize the discrepancy between local fixed control coordinates ($NE_{control}$) and projected grid coordinates (N’E’). The horizontal adjustment solves parameter translations in north and east (ΔN, ΔE), a rotation ϕ, and a scale factor k using two different sets of plane coordinates—one converted from measurements in the field, and the other from a control list. Where the Survey Controller generates its own three-parameter datum transformation, it is necessary to provide for scaling and rotation. This is done by a horizontal adjustment.

Figure C-1 shows the transformation between two coordinate systems.

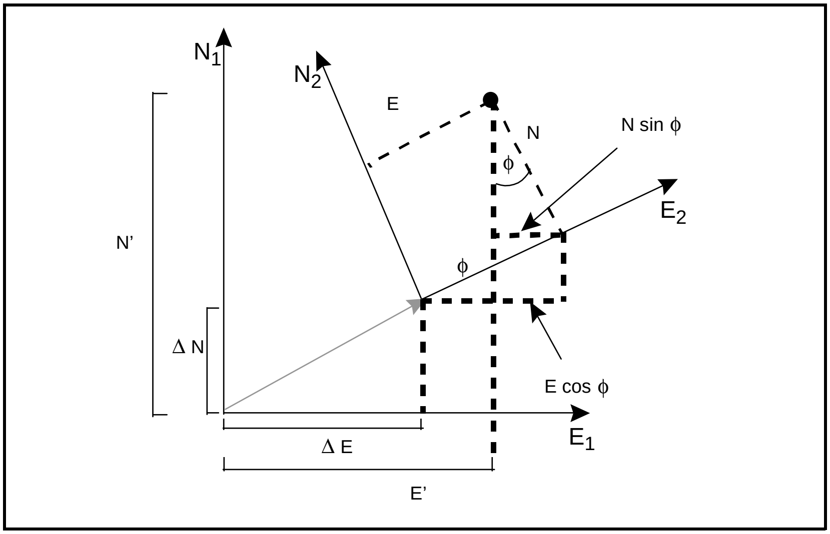

Figure C-1 Coordinate Systems for a Horizontal Adjustment

The Survey Controller minimizes the discrepancy between local NE control and NE values derived using GPS observations and a datum transformation and map projection. It does this by performing a plane horizontal least-squares adjustment with no weighting.

In the trivial one point case, the translation parameters are just the Northing and Easting components of the vector between the two coordinated values. The scale factor is one, and the rotation value is zero.

For two or more points, calculation of horizontal adjustment uses a simple four-parameter transformation. This solves for two translations (ΔN, ΔE), a rotation (ϕ), and a scale factor (*k*) between coordinate pairs.

The geometry between the two coordinate systems results in two transformation equations:

$$N' = aN + bE + \Delta N \qquad (16)$$

$$E' = -bN + aE + \Delta E \qquad (17)$$

where $a = k \cos\phi$ and $b = k \sin\phi$ are used to simplify the matrix representation, and ΔN and ΔE represent the shifts of the N and E axis in the N' and E' system.

Common points in both coordinate systems are used in a least-squares adjustment to solve the four unknown parameters (a, b, ΔE, and ΔN).

Once estimates of a and b are determined, the rotation and scale between the two systems is calculated by:

$$\phi = \tan^{-1}\left(\frac{a}{b}\right) \text{ and } k = \sqrt{a^2 + b^2} \qquad (18)$$

For more information about horizontal adjustment, please refer to *Observations and Least Squares* by E. Mikhail (John Wiley & Sons, 1982).

C.1.5 Vertical Adjustment

The Survey Controller software determines a vertical adjustment using least-squares with no weighting. This adjustment requires measured WGS-84 heights and control elevations.

In the trivial one-point case, the adjustment consists of a constant height shift only. For two or more points, a tilt in north and east are also computed. The inclined plane parameters are determined by solving the matrix equation:

$$AX = B \tag{19}$$

where the solution

$$X = \begin{bmatrix} \Delta H \\ \Delta E \\ \Delta N \end{bmatrix} \tag{20}$$

the components being the constant height shift and tilt east and north (in terms of a height shift per unit distance east or north), and the design matrix

$$A = \begin{bmatrix} 1 & E_1 - E_1 & N_1 - N_1 \\ 1 & E_2 - E_1 & N_2 - N_1 \\ & : & \\ 1 & E_n - E_1 & N_n - N_1 \end{bmatrix} \tag{21}$$

where E_n N_n are the coordinates of the *n*th point as derived from the WGS-84 data set.

E_1 N_1 are the coordinates of the origin point of the adjustment. (The origin point can be any one of the *n* points.)

$$B = \begin{bmatrix} H'_1 - H_1 \\ H'_2 - H_2 \\ \vdots \\ H'_n - H_n \end{bmatrix} \qquad (22)$$

where $H'_n - H_n$ is the difference in elevation between the keyed in value for the *n*th point and the value derived from the WGS-84 data set.

C.2 Geoid Model

The Survey Controller software can use a geoid model to provide orthometric heights from measured (by GPS) WGS-84 heights.

Geoid model is one of the options in the *Vertical adjustment* field. (The other options in this field are No adjustment, Inclined plane, Geoid model/Inclined plane.) For information on how to select a Geoid model see Using a Geoid Model, page 5-11.

C.2.1 In-Field Calibration

If you select Geoid model and you do not perform an in-field calibration, the elevation values displayed by the Survey Controller represent the unadjusted elevation above the defined geoid using the relationship:

$$h_{geoid} = H - N \qquad (23)$$

where:

h_{geoid} = the unadjusted elevation above the geoid

H = the measured GPS height above the ellipsoid

N = the geoid ellipsoidal separation, derived from a geoid model

If you select Geoid model and perform an in-field calibration, the Survey Controller computes the calibration parameters using $h_{control}$ and h_{geoid} as inputs, so that the geoid model is inclined to fit the local control elevations. The method of vertical adjustment becomes Geoid/Inclined plane.

C.3 Survey Controller Measurement Precision

Precision values are not displayed for autonomous GPS positions (points that will be postprocessed).

For real-time kinematic and differential surveys, the precision values displayed reflect the GPS instrument precisions. These are similar to the day-to-day repeatability of survey observations except they do not take into account multipath, other environmental noise, and incorrect reference station coordinates.

The precision values are determined from the following:

$$\text{horizontal precision} = \text{HDOP} * \text{RMS} * 3.0 \qquad (24)$$

$$\text{vertical precision} = \text{VDOP} * \text{RMS} * 3.0 \qquad (25)$$

where HDOP and VDOP are the horizontal and vertical dilution of precision respectively. RMS (Root Mean Square) is the solution RMS for the L1 phase observation in meters, and is the radius of the error ellipse within which approximately 70% of position fixes will be found. The precision values are scaled to ~ 99% confidence level by multiplying by a factor of three.

Both float and fixed solutions use the same formula. The loss of precision indicated in float solutions is due to an increase in the RMS value where the integer ambiguities are not fixed. Real-time precision statistics cannot be displayed while a receiver is roving (moving), if there are less than five satellites being tracked.

C.4 Area Calculations

When we calculate the area in *Cogo* / *Compute area*, it is calculated at the average elevation of all the points when the *Distances* field is set to Ground. Average elevation is calculated as follows:

calculate

$$\bar{h} = \frac{\sum h_i}{N} \qquad (26)$$

then

$$\left(\frac{\bar{h} + R}{R}\right)^2 \text{ X area at sea level} \qquad (27)$$

where:

N = number of stations

$\bar{h}$ = average elevation

R = ellipsoidal radius

C.5 Ellipsoid Calculations

The ground and sea level distances in the Survey Controller are calculated parallel to the ellipsoid. The equations used for these calculations are based on the Robbins ellipsoid geometry formulas. These formulas (by Dr A.R. Robbins) are in the *Empire Survey Review* No. 125, 1962. They are accurate to better than 20 mm over distances of 1,500 km. The errors can reach 16 meters at 4,500 km and more than 2,000 meters at 9,000 km.

C.6 Conventional Instrument Calculations

Figure C-2 shows the position of the corrections applied when you use the Survey Controller software with a conventional instrument.

Note – Interim corrections are not shown in the figure. They are enclosed in square brackets in the text that follows.

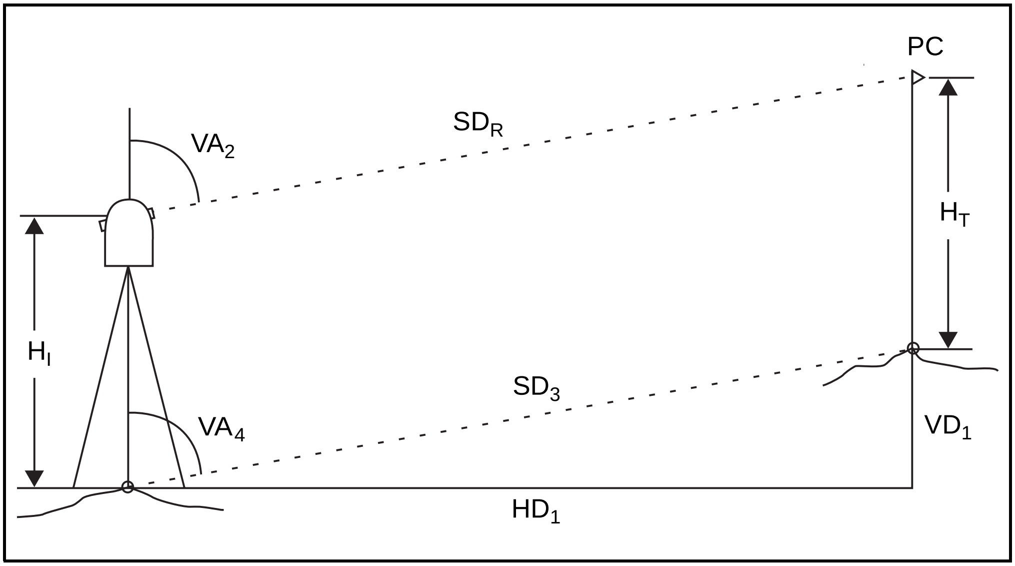

Figure C-2 Correction Variables Used in Conventional Instrument Calculations

Where:

VA_2 = Vertical angle from conventional instrument

Note – The Survey Controller assumes that the conventional instrument applies any corrections for collimation and tilt. [VA_1 is the vertical angle before these corrections are applied.]

[VA_3 = Vertical angle corrected for curvature and refraction]

VA_4 = Vertical angle corrected for curvature and refraction, instrument and target heights

SD_R = Slope distance from EDM

[SD_1 = Slope distance corrected for prism constant (PC)]

[SD_2 = Slope distance corrected for prism constant and PPM]

SD_3 = Slope distance corrected for prism constant, PPM, instrument and target heights

HD_1 = Horizontal distance between instrument point and target point

VD_1 = Vertical distance between instrument point and target point

H_I = Height of instrument

H_T = Height of target

PC = Prism constant

C.6.1 Prism Constant Correction

The prism constant is applied to all slope distances. It is usually negative, but can be positive.

$$SD_1 = SD_R + PC \quad (28)$$

where:

SD_R = measured (raw) slope distance

SD_1 = resultant slope distance

PC = prism constant

C.6.2 PPM Correction

The parts per million (PPM) correction is applied to the slope distance after being corrected for the prism constant (see above). PPM depends on pressure and temperature.

$$SD_2(P, T) = SD_1\left[\frac{N \cdot P}{273.16 + T}\right] \cdot 10^{-6} \quad (29)$$

where:

P = air pressure in millibars

T = temperature in °C

J and N= constants supplied by the EDM manufacturer

Table C-1 lists some manufacturers of conventional instruments, and the J and N constants that the Survey Controller software uses to compute the PPM correction for those instruments.

Table C-1 PPM Constants for Conventional Instruments

Manufacturer of conventional instruments	J constant	N constant
Trimble	270.0	79.2
Sokkia SET	279.0	79.4
Topcon	279.7	79.6
Geotronics	275.0	79.55
Leica	282.0	79.4
Zeiss	255.0	79.1

C.6.3 Curvature and Refraction Correction

The curvature and refraction correction is applied to vertical angles according to the coefficient of refraction that you set.

$$VA_3 = VA_2 - \left[\frac{(1-k)SD_3}{2R}\right] \cdot \frac{180}{\pi} \qquad (30)$$

where:

k = coefficient of terrestrial refraction, selected in the *Corrections* field in the Survey Style

R = approximate spheroid radius = 6378137.298 (WGS-84 semi-major axis)

SD_3 = slope distance, from Equation (32)

VA_2 = vertical angle, from instrument

VA_3 = corrected vertical angle

C.6.4 Instrument and Target Height Reduction

The corrected vertical angle (VA_4) from the instrument to the target is:

$$VA_4 = \tan^{-1}\left[\frac{SD_2 \sin VA_3}{SD_2 \cos VA_3 + H_I - H_T}\right] \qquad (31)$$

where:

H_I = instrument height

H_T = target height

SD_2 = slope distance

VA_3 = vertical angle, from Equation (30).

VA_4 = corrected vertical angle

The slope distance from source point to target point (SD_3) is given by the following:

$$SD_3 = \frac{SD_2 \sin VA_3}{\sin VA_4} \quad (32)$$

C.6.5 Face 1/Face 2 Determination

This section describes how the Survey Controller software reduces Face 2 readings to Face 1 readings in order to perform calculations. It does this automatically.

The observed raw vertical angle is used to determine whether an observation is Face 1 or Face 2:

- If the vertical angle is not present the observation is assumed to be Face 1.
- If the vertical angle is in the range 0° to 180°, the observation is Face 1.
- If the vertical angle is in the range 180°–360°, the observation is Face 2.

C.6.6 Orientation Correction

To orient circle readings so that they become azimuths, an orientation correction is applied. The orientation correction is the difference between the backsight circle reading and the backsight azimuth. This term is applied to all the other observations (circle readings) at a station.

The formula is:

$$Az_{\chi} = HA_{\chi} + (Az_B - HA_B) \quad (33)$$

where:

Az_x = azimuth to any point X

HA_x = observed bearing to any point X

Az_B = actual backsight azimuth ('reference azimuth')

HA_B = observed backsight circle reading

C.6.7 Slope Reduction

The horizontal and vertical components of an observation (HD_1 and VD_1) are found from the vertical angle and slope distances by:

$$HD_1 = SD_3 \sin VA_4 \quad (34)$$

$$VD_1 = SD_3 \cos VA_4 \quad (35)$$

where:

HD_1 = horizontal distance

VD_1 = vertical distance

VA_4 = zenith angle

SD_3 = slope distance

C.6.8 Coordinate Calculation

Coordinates of a target point are calculated from observations and the coordinates of the instrument point using:

$$N_2 = N_1 + HD_1 \cos Az_1 \quad (36)$$

$$E_2 = E_1 + HD_1 \sin Az_1 \quad (37)$$

$$Z_2 = Z_1 + VD_1 \quad (38)$$

where:

N_1, E_1, Z_1 = Northing, Easting, Elevation of instrument point

N_2, E_2, Z_2 = Northing, Easting, Elevation of target point

HD_1 = horizontal distance

VD_1 = vertical distance

Az_1 = from Equation (33)

C.6.9 Resection Calculation

The resection calculation is a least-squares calculation that uses all available data.

Observations to the same point taken on different faces are treated as separate observations. However, the results are the same as those gained from using meaned (averaged) observations.

The residuals are given for each ***point***, not each observation.

C.7 The Survey Controller Database

The Survey Controller software includes a dynamic database. This stores networks of connected vectors during RTK and conventional surveys, making the positions of some points dependent on the positions of others. If you change the coordinates of a point that has dependent vectors (an instrument station, a backsight point, or a GPS base station, for example), this affects the coordinates of all points that depend on it.

You can change the coordinates of a point. To do this:

- Measure another point with the same name as the existing point.
- Key in another point with the same name as the existing point.

The new point of that name may have a different position from the original point.

The Survey Controller software uses database search rules to resolve the coordinates of dependent points based on the new coordinates for a point. If the coordinates of a point with dependent points moves by a certain amount, the dependent points are shifted by the same amount.

If a point name already exists in the database, the Survey Controller generally issues a duplicate point warning message when you try to store a point with the same name.

Note – If this happens, you could be about to overwrite a point that has dependent vectors. The coordinates of the dependent vectors could change.

In some situations, you cannot overwrite a point that has dependent vectors. The following message appears:

```
The position of the current station depends on
this point. Cannot overwrite.
```

This happens if you try to close a loop of observations in a conventional survey. The message appears when you observe and then try to store a point with the same name as the original backsight or instrument point. Store the point as a Check class point, or give it a different name.

C.8 Database Search Rules

This section explains the database search rules relevant to the Survey Controller database.

The Survey Controller software lets multiple points with the same point name (point ID) exist in the same job:

- If you ***measure*** a point with a name that already exists in the database, you can overwrite the original point when you store the new one. If the original point has the same or a lower search class, it is deleted.

Note – Deleted points remain in the database and have a search class of Deleted. For more information see Search Class, page C-27.

- If you ***key in*** a point with a name that already exists in the database, the original point is not deleted. Both points are stored in the database, and both are downloaded with the job. The Survey Controller search rules make sure that only the second point is used for calculations.

Tip – To get rid of the first point, delete it manually when you review the job.

To distinguish between these points of the same name and to decide how these points are to be used, the Survey Controller software applies a set of search rules. When you ask for the coordinates of a point in order to perform a function or calculation, these search rules sort the database according to:

- the order in which the point records were written to the database
- the classification (search class) given to each point

C.8.1 Order in the Database

A database search starts at the end of the job database and works backwards to the beginning of the job, looking for a point of the name specified.

Note – The search is in reverse chronological order.

The Survey Controller first finds the most recent point of that name (for example, the last point that you stored with that name). It then searches the rest of the database for points of the same name. Basically:

- If two or more points have the same class as well as the same name, it uses the most recent point.
- If two or more points have the same name but different classes, it uses the point of higher class, even if this is not the most recent point.

C.8.2 Search Class

The Survey Controller software gives every point a classification. It uses this classification to determine the relative importance of points stored in the job database, as well as their uses.

The classes are arranged in a descending hierarchy, as follows:

- Control – (the highest class) can only be set when a point is keyed in or uploaded.
- Normal – is given to all measured points apart from staked points. Uploaded points can also be given this class.
- As-staked – is given to points measured during stakeout.
- Backsight – is given to observations made to the backsight point during a station setup and to observations made during a resection.
- Check – (the lowest class) is given to a conventional check point observation, or a GPS point measured with a duplicate name and stored as a Check class point. For more information see Duplicate Point Actions, page 7-26.
- Deleted – is given to points that have been overwritten, where the original point had the same (or a lower) search class than the new point. It is also given to points/lines/curves and roads that were deleted manually in the job database.

Note – You cannot overwrite a Control class point with a measured point.

Deleted points are not displayed in point lists and they are not used in calculations. They do, however, remain in the database.

Control class is used in preference to Normal, As-staked, Backsight, or Check class. It can only be set by you. Use Control class for points that you want to use in preference to points of the same name in the same job database. For more information see Assigning Control class to a point, page C-29.

Normal class is used in preference to As-staked, Backsight, or Check class, and As-staked class is used in preference to Backsight or Check class.

If points have the same class as well as the same name, the point most recently added to the database is used.

Example

If the Point 1000 is entered as the first point in a From Baseline offset, the Survey Controller software looks for the most recent (latest) version of Point 1000. It then searches the rest of the database looking for any point named 1000:

- If no other point of this name is found, it uses the one it has to calculate the offset.
- If another Point 1000 is found, the Survey Controller compares the classes of the two points. It uses the Point 1000 that has the highest classification.

  If both points were keyed in and one was given a Normal classification, the other a Control classification, the Survey Controller uses the Control class point to calculate the offset—regardless of which record the search finds first.
- If the points are of the same class, the Survey Controller uses the more recent one.

  If both points named 1000 were keyed in and both were given a Normal classification, the Survey Controller uses the more recent one.

Assigning Control class to a point

Control class is the highest classification that you can give to a point. Any high-accuracy point that you use as a fixed standard in a job can be a Control point.

If you set the search class to Control when you key in the coordinates for a point, you can be sure that those coordinates will not change until you key in another point of the same name and the same search class.

The Survey Controller software never elevates measured points to Control class. This is because measured points have measurement errors and may change or be measured again during the course of the job. If the keyed in point CONTROL29 is Control class, generally you would not want the coordinates of that point to change. A Control class point is held fixed for the job. For example, if the Survey Controller did store a measured point called CONTROL29 with Control classification later in the file, the original uploaded or keyed in point that appears earlier in the job database would not be used for calculations such as Cogo calculations. Instead, the measured one—which could be wrong, or in a different place—would be found and used. Effectively, your Control class point would be overwritten.

The Survey Controller can measure control points—kinematic control points—but it does not give them Control classification. This is because, in calibration, the measured point often has the same name as the keyed in control point. This makes it easier to set up the calibration. It also makes it easier to manage your data if you know that all references to point CONTROL29 on the ground, for example, are also references to point CONTROL29 in the database.

Exceptions to the search rules

There are two cases when the usual search rules are not used. They are:

- in calibration
- when starting an RTK rover

Calibration searches for the highest class point stored as grid coordinates. This grid point is used as one of a pair of calibration points. The Survey Controller software then searches for the highest class GPS point stored as WGS-84 coordinates or as a WGS-84 vector. This point is used as the GPS part of the point pair.

If the broadcast base point is called BASE001, choosing *Start survey* at the start of a rover survey causes the Survey Controller to search for the highest class GPS (WGS-84) point of that name. If no GPS point exists with the name BASE001, but BASE001 exists with grid or local coordinates, the Survey Controller software converts the grid or local coordinates of the point into a GPS (WGS-84) point. It uses the projection, datum transformation, and current calibration to calculate the point. It is then stored, as BASE001, with WGS-84 coordinates and is given a Check class classification so that the original grid or local coordinates will still be used in calculations.

Note – The coordinates of the base point in the Survey Controller database are the coordinates from which GPS vectors are solved.

If there is no point in the database, the position broadcast by the base is stored as a Normal class point and it is used as the base coordinates.