# British Columbia
# Specifications and Guidelines
# For
# Control Surveys Using
# Conventional Survey Technology

BRITISH COLUMBIA
The Best Place on Earth

Integrated Land Management Bureau

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# APPENDICES

# LIST OF ACRONYMS

| | |
|---|---|
| 1D, 1-D | One-dimensional |
| 2D, 2-D | Two-dimensional (e.g. horizontal North / East) |
| 2DRMS | Twice the distance RMS (Root Mean Square) |
| 3D, 3-D | Three-dimensional |
| A-S | Anti-Spoofing (encryption of the P- code to the Y- code) |
| BC | Province of British Columbia |
| BCACS | British Columbia Active Control System |
| BCGS | British Columbia Grid System |
| BCGSR | British Columbia Geo-Spatial Reference |
| BCLS | British Columbia Land Surveyor |
| CRGB | Crown Registry and Geographic Base Branch |
| C/A | Coarse/Acquisition GPS signal (civilian) |
| CACS | Canadian Active Control System |
| CADD | Computer Aided Drafting & Design |
| CCG | Canadian Coast Guard |
| CEP | Circular Error Probable (50% confidence) |
| CSRS | Canadian Spatial Reference System |
| CVD28 | Canadian Vertical Datum 1928 (orthometric elevations) |
| CDGPS | Canada-wide Differential GPS |
| CGG2000 | Geodetic Survey Division year 2000 Geoid model for NAD83 ellipsoid to orthometric height conversion (also see HT2_0) |
| DGPS | Differential GPS |
| DOP | Dilution Of Precision |
| DRMS | Distance Root Mean Square (see 2DRMS) |
| DXF | Drawing eXchange Format (CAD drawing exchange format) |
| ECEF | Earth-Centered, Earth-Fixed |
| EDOP | East DOP |
| GALILEO | European GNSS (similar to GPS) |
| GCM | Geodetic Control Monument |
| GDOP | Geometric DOP (3D plus Time) |
| GIS | Geographic Information System |
| GeoBC | Geographic Infrastructure of British Columbia |
| GLONASS | Russian GNSS (similar to GPS) |
| GNSS | Global Navigation Satellite System (GPS, GALILEO, GLONASS, etc) |
| GPS | Global Positioning System (also called NAVSTAR by military users) |
| GRS | Geodetic Reference System |
| GSD | Geodetic Survey Division, Natural Resources Canada (NRCan) |
| GSR | Geo-Spatial Reference |
| HDOP | Horizontal DOP (2D) |
| HT2_0 | Height transformation based on the CGG2000 Geoid model with corrections (used to transform GPS ellipsoidal heights to CVD28 orthometric elevations) |
| Hz | Hertz (1/second) |

| | |
|---|---|
| IERS | International Earth Rotation Service |
| ILMB | Integrated Land Management Bureau (Ministry of Agriculture and Lands) |
| IGDS | Interactive Graphic Design System |
| INCOSADA | Integrated Corporate Spatial and Attribute Database (MoF) |
| ISA | Integrated Survey Area |
| ITRF | International (IERS) Terrestrial Reference Frame |
| L1 | GPS L-band signal 1 (1575.42 MHz) |
| L2 | GPS L-band signal 2 (1227.6 MHz) |
| L5 | GPS L-band signal 5 (1176.45 MHz)…not in service yet. |
| LAAS | Local-Area Augmentation Service |
| LADGPS | Local-Area Differential GPS |
| L-band | L-band frequency (about 1-2GHz) of the electromagnetic spectrum |
| MGSR | Municipal Geo-Spatial Reference |
| MoFR | Ministry of Forests and Range |
| MSL | Mean Sea Level |
| NAD27 | North American Datum 1927 |
| NAD83 | North American Datum 1983 |
| NAD83 CSRS) | NAD 1983 (Canadian Spatial Reference System) |
| NANU | Notice Advisory to NAVSTAR (GPS) Users |
| NAVD88 | North American Vertical Datum 1988 (USA) |
| NAVSTAR | Navigation Satellite Timing And Ranging (US military acronym for GPS) |
| NDOP | Northing DOP |
| NRCan | Natural Resources Canada (Federal Government) |
| OEM | Original Equipment Manufacturer |
| P-code | Precise code – provided for military GPS users and selected others |
| PDOP | Position DOP (3D) |
| PoC | Point of Commencement |
| PoT | Point of Termination |
| PPM | Part Per Million (i.e. 1mm per 1km) |
| PPS | Precise Positioning Service (military) |
| PR | Pseudorange |
| PRC | Pseudorange Correction |
| PRN | Pseudo Random Noise code (unique code for each satellite) |
| PSGUC | Public Sector GPS Users Committee |
| QA | Quality Assurance |
| QC | Quality Control |
| RIB | Resources Inventory Branch, Ministry of Forests |
| RISC | Resources Information Standards Committee |
| RINEX | Receiver Independent Exchange format |
| RMS | Root-Mean-Square |
| RTCA | Radio Technical Commission for Aeronautical services |
| RTCM | Radio Technical Commission for Maritime services |
| RT-DGPS | Real Time Differential GPS |
| RTEB | Resource Tenure and Engineering Branch, Ministry of Forests |
| RRC | Rate of the Range Correction (broadcast by RT-DGPS systems) |
| Rx | Receiver (i.e. GPS Rx) |
| SA | Selective Availability (civilian degradation, removed 2$^{nd}$ May, 2000) |

| | |
|---|---|
| SAIF | Spatial Archive and Interchange Format |
| SEP | Spherical Error Probable (50% confidence) |
| SNR | Signal to Noise Ratio |
| SPS | Standard Positioning Service (civilian) |
| TDOP | Time DOP |
| TRIM | Terrain Resource Integrated Mapping |
| UTC | Universal Time Coordinated |
| UTM | Universal Transverse Mercator |
| VDOP | Vertical DOP (1D) |
| WAAS | Wide-Area Augmentation Service |
| WADGPS | Wide-Area Differential GPS |
| WGS84 | World Geodetic System 1984 |
| Y-code | Encrypted P code (Anti-Spoofing) |

# 1. INTRODUCTION

The provincial Geo-Spatial Reference (GSR) coordinate system is defined and managed by Crown Registry & Geographic Base (CRGB) branch, of the Ministry of Agriculture & Lands. This coordinate system is used to support a wide variety of positioning activities throughout the province.

The current GSR consists of both a passive monumented system (physical monuments in the ground), and an active 'GPS space-based' system called the BC Active Control System (BC-ACS). A goal of CRGB is to enhance the GPS based referencing system, and thus allow less emphasis to be placed on the physically monumented system. However, it is recognized that the physically monumented system is a popular system being used by many surveyors. As an example, many municipalities continue to develop physically monumented survey control networks, and therefore specifications and guidelines are required to ensure that these monuments are properly integrated within the existing provincial system. Municipal survey control networks are referred-to as Municipal Geo-Spatial References (MGSR).

CRGB maintains the MASCOT provincial survey control database which provides published coordinates, elevations and related data for public access and use. Mapping and control surveys are the primary methods for integrating new survey control monuments into the MASCOT database.

This document provides standards for geodetic control surveying using conventional surveying techniques. The primary intent of this document is to define conventional surveying procedures and standardized submissions that will be accepted by CRGB for integration into the MASCOT database.

Spirit levelling is the preferred method for establishing and maintaining elevations in the vertical geo-spatial reference in the province. Section 2.3 and 2.4 describe spirit levelling techniques that are included in these specifications, with updated references to the use of digital levels.

Using GPS technology has superseded traditional conventional survey methods as the primary horizontal survey methodology for integrating new controls into the GSR. A parallel document exists describing these methods: *British Columbia Specifications and Guidelines for Control Surveys using GPS Technology*. However, it is recognized that there are some situations where conventional horizontal surveying techniques may be more suitable than GPS, or may supplement a GPS survey, and therefore it is necessary to still maintain conventional control specifications and guidelines to ensure a homogeneous integration of all survey data.

Geodetic horizontal control surveys involve the integration of new monuments into the existing provincial GSR. Each monument is assigned a unique Geodetic Control Monument (GCM) number. The provincial GSR differentiates between GCMs that are located within an MGSR, and GCMs that are located outside of an MGSR. Municipal MGSRs are typically established to support internal survey and mapping applications performed within the municipality. Survey control established outside of an MGSR is usually for a specific project application (e.g. well-site surveys, Land Claim control, mapping control, etc.). Conventional survey procedures and network design considerations are described in this document for both surveys inside and outside of MGSRs.

Although these specifications have been updated to reflect changes in conventional survey technology, many of the field procedures and methodologies are still based on recommendations contained in *Specifications and Recommendations for Control Surveys and Survey Markers, 1978* as published by the Surveys and Mapping Branch, Federal Department of Energy, Mines, and Resources, Canada. CRGB support the use of the recommendations contained in this document only for historical reference only – as also referred by Natural Resources of Canada.

The *Province of British Columbia Accuracy Standards for Positioning (July 2009)* defines accuracy standards for horizontal coordinates, ellipsoidal heights, and orthometric heights. For each case the accuracy can be expressed as the *Network Accuracy* describing the absolute accuracy with respect to the defining reference frame, and it can also be expressed as the *Local Accuracy* describing the relative accuracy with respect to adjacent stations. These accuracy measures are computed at the 95% confidence level, and can be grouped into "classes" labelled with the upper boundary value (e.g. 0.02m). Note that these accuracy standards have changed since the "traditional" definitions using various accuracy "orders", and these standards apply to both GPS and conventional surveys. It is recommended that the accuracy standards document be read and understood before reading this document.

As a reference note that applies to this document; currently GPS terminology only applies to US Defence owned satellite navigation system, where lately this expression is replaced by GNSS (Global Navigation Satellite System). GNSS terminology includes US owned *GPS*, Russian Federation owned *GLONASS*, European Union owned *Galileo*, and China owned *COMPASS* navigation systems. During the update of this document, of all GNSS, only GPS is fully operational and GLONASS is considered to be a useful addition to increase productivity (not fully functional). Nearly all navigation system manufacturers have integrated GNSS compatibility within their hardware and users now have the option to employ GNSS or not in their daily work.

# 2. VERTICAL CONTROL SURVEYS

This Section contains accuracy standards, specifications, and guidelines for establishing vertical control using conventional surveying techniques. Heights in this document are assumed to be orthometric (rather than ellipsoidal which would be associated with GPS surveys). The main focus of the guidelines is the required equipment and observation techniques appropriate for two typical conventional spirit levelling control projects conducted for government: 1) High Precision Network (HPN) Surveys, and 2) Municipal Geo-Spatial Reference (MGSR) Surveys. Although the guidelines focus on these two types of vertical control surveys, the procedures and methodologies outlined here can be used for other conventional levelling projects with similar accuracy requirements.

Note that for both HPN and MGSR vertical surveys, the specific levelling observations required are usually prescribed for each project. This observation planning is done with consideration for accuracy, integration with neighbouring vertical networks, redundancy, route issues, time/cost, etc. A simulated Least Squares (LS) adjustment calculation may be used during the planning stage of a project to help refine the vertical observation network.

## 2.1. ACCURACY STANDARDS

The orthometric height accuracy can be expressed as *Network Accuracy* and/or *Local Accuracy* as defined by the 95% confidence intervals resulting from LS adjustments. The orthometric *Network Accuracy* is not generally accessible because of the nature of the defining vertical datum (and full station covariance information is not typically published). The orthometric *Local Accuracy* can be used to describe the relative accuracy with respect to adjacent stations, and this can be computed by a LS adjustment of the vertical observations. However, most conventional vertical surveys are instead specified based on an allowable discrepancy between independent height-differences measured between benchmarks or in closed loops. Note that this reflects the precision of the measurements, rather than the accuracy of the resulting heights. This is a practical method for surveyors to simply confirm the precision of their observations in the field. The allowable discrepancies are described below:

| | |
|---|---|
| HPN Surveys | $\pm$ 4mm $\sqrt{K}$ |
| MGSR Surveys | $\pm$ 16mm $\sqrt{K}$ |
| Trigonometric Levelling | $\pm$ 75mm $\sqrt{K}$ |

*K is the one-way distance in kilometres between benchmarks or the length of loop measured along the levelling route*.

Note that some projects may specify precision describing allowable discrepancies, as well as a *Local Accuracy* requirement. This would be expected on large projects (e.g. HPN Surveys) that have a network of many inter-connected height-difference observations. This type of vertical network would be adjusted using LS techniques.

# 2.2. HPN LEVELLING SPECIFICATIONS AND GUIDELINES

## 2.2.1. CONTROLLING BENCHMARKS

All HPN levelling shall include ties to *at least three* controlling benchmarks. Controlling benchmarks will typically be pre-selected based on their underlying accuracy and also their location relative to the new survey area.

Controlling benchmarks must be confirmed using a ‘valid check’ procedure. A ‘valid check’ is a confirmation that the observed elevation difference agrees with the published elevation difference within the allowable tolerance of the survey (in this case $\pm$ 4mm $\sqrt{K}$). If a controlling benchmark fails the ‘valid check’ confirmation, then additional observations will be required. These additional observations may be in the form of a closing level loop, or extending the levels to include an additional controlling benchmark, or repeating the original level run.

## 2.2.2. EQUIPMENT

Any level/rod combination can be used, provided that the manufacturer’s equipment specifications as well as the required calibrations and tests verify that they are capable of attaining the required precision.

If using ‘optically read’ levelling equipment, it is recommended that self-levelling or spirit-level instruments equipped with a parallel-plate micrometer and a telescope magnification of at least 32X be used. The minimum repeatability of line of sight should be 0.25” with a least count of 0.1mm. Level rods should be one piece invar, double-scaled.

If using an electronic digital/bar-code levelling system, the minimum repeatability of line of sight should be 0.40” with a least count of 0.01mm. Level rods should be one piece invar, single-scaled.

Substantial foot plates (turtles) are required for turning points, rod levels are to be used, and tripods with fixed-length legs are required.

## 2.2.3. PROCEDURES

The HPN levelling procedures described here were extracted from the document: ***A Guide to Precise Levelling (1988 Revision)*** published by Geodetic Surveys Division, Natural Resources Canada. However, this document is no longer available for public use.

1) The following calibrations and checks must be conducted on a regular basis and if deemed necessary equipment adjustments performed.

    a) Circular bubble tests,

  *b)* Rod verticality tests
  *c)* Instrument collimation checks (Two Peg Test)

2) A two-rod levelling system should be used.
3) All sections must have an even number of instrument set-ups.
4) Backsight – Foresight – Foresight – Backsight (BFFB) procedures per set-up are required as follows:
   a) Backsight, low-scale
   *b)* Backsight stadia
   *c)* Foresight, low-scale
   *d)* Foresight stadia
   *e)* off-level / re-level
   *f)* Foresight, high-scale
   *g)* Backsight, high-scale

5) The low/high scale elevation differences for one set-up must not exceed 0.3mm.
6) Maximum length of sight should not exceed 60m.
7) Foresight and Backsight distances should not differ by more than 5m at each setup, and the total difference per section should not differ by more than 10m.
8) Line of sight should not be less than 0.5m above the ground.

When using an electronic digital/bar-code levelling system the following procedures should be used in addition to or in place of those described above:

1) Collimation error determinations are required at the beginning of each day (0.05mm/m = 10 arc seconds). Collimation data must be recorded with the levelling data and the daily updated value must be used during the daily data capture.
2) BFFB procedures per set-up are required as follows:
   a) Backsight
   *b)* Backsight distance, standard error
   *c)* Foresight
   *d)* Foresight distance, standard error
   *e)* off-level / re-level
   *f)* foresight, standard error
   *g)* Backsight, standard error

3) The two elevation differences for each set-up (before and after re-levelling) must be <0.3mm.
4) Vibration of the compensator can affect the observations. The digital level should be configured to automatically mean at least 3 individual measurements per pointing, and the standard deviation should be computed and displayed. If the standard deviation is greater than 0.3mm, the measurement should be repeated.
5) Digital level observations can be adversely affected by poor image contrast, particularly when the sun is low on the horizon and near the line of sight. To this problem the telescope sun shade should be used, and the sight distance should be reduced. Another problem can be caused by light entering through the eyepiece when the instrument person does not continue

to look through the telescope during the measurement process. This can be the case if they are looking up in anticipation of reviewing the data. If this causes measurement problems, the eyepiece should be shaded to prevent stray light entering.

6) Observations using the extreme ends of the levelling staff may not be as accurate as using the middle section. For HPN levelling, observations should not use the top or bottom 0.5m of the rod for sight lengths of 50m, and the top or bottom 0.3m of the rod for sight lengths of 30m.

## 2.3. MGSR LEVELLING SPECIFICATIONS AND GUIDELINES

### 2.3.1. CONTROLLING BENCHMARKS

All MGSR levelling shall include ties to at least two controlling benchmarks. Controlling benchmarks will typically be pre-selected based on their underlying accuracy, their location and their proximity distance relative to the new survey area.

Controlling benchmarks must be confirmed using a 'valid check' procedure. A 'valid check' is a confirmation that the observed elevation difference agrees with the published elevation difference within the allowable tolerance of the survey (in this case $\pm$ 16mm $\sqrt{K}$). If a controlling benchmark fails the 'valid check' confirmation, then additional observations will be required. These additional observations may be in the form of a closing level loop, or extending the levels to include an additional controlling benchmark, or repeating the original level run.

### 2.3.2. EQUIPMENT

Any level/rod combination can be used, provided that the manufacturer's equipment specifications as well as the required periodic calibrations verify that they are capable of attaining the required precision. A calibration report may be required for measurement submission to CRGB.

The recommended level types for MGSR projects are: self levelling instruments having a compensator with a sensitivity equal to or better than 20" per 2 mm level vial, or spirit level instruments with a 20" per 2 mm or better level vial, or an electronic digital/bar-code levelling system with a minimum repeatability of line of sight of 0.80" with a least count of 0.1mm.

It is recommended that rods should be invar double scale with line graduations between 1 mm and 1.6 mm wide if the level does not have a parallel plate micrometer, or with line graduation no larger than 1 cm if the level has a parallel plate micrometer. Rods with line graduations on wood or metal alloy are acceptable; however, it is important that the graduations be accurate to within 1 mm.

It is recommended that rod level bubbles and foot plates (turtles) for turning points are used.

### 2.3.3. PROCEDURES

1) The following calibrations and checks must be conducted on a regular basis, and if deemed necessary equipment adjustments performed.

    a) Circular bubble tests,
    b) Rod verticality tests
    c) Instrument collimation checks (Two Peg Test)

2) A two-rod levelling system is recommended, but a single-rod procedure is acceptable.
3) All sections must start and end with the same rod.
4) Alternate readings of Backsight and Foresight shall be made at successive set-ups (BF method).
5) Only single wire readings are required, but some method of maintaining even Backsight / Foresight distances must be employed.
6) Difference between Backsight and Foresight distances at each set-up should not exceed 10m, and the difference between the total Backsights and Foresights for each section should not exceed 20m.
7) Maximum length of sight shall be 60m.
8) Level lines may be run in one direction only in loops between controlling benchmarks.
9) When using a electronic digital/bar-code levelling system the following procedures should be used in addition to or in place of those described above :

    a) For electronic digital/bar-code systems, collimation error determinations are required at the beginning of each day (0.05mm/m = 10 arc seconds). Collimation data must be recorded with the levelling data and the daily updated value must be used during the daily data capture.

    b) Vibration of the compensator can affect the observations. The digital level should be configured to automatically mean at least 2 individual measurements per pointing, and the standard deviation should be computed and displayed. If the standard deviation is greater than 0.5mm, the measurement should be repeated.

## 2.4. TRIGONOMETRIC LEVELLING

In some situations it may be impractical to conduct differential spirit levelling, and trigonometric levelling techniques may be the best alternative method. In this case, CRGB shall be notified prior to conducting the survey. Trigonometric levelling should only be conducted on relatively short lines (e.g. a few hundred metres) in order to obtain reliable results. The height difference accuracy that can be achieved depends on the accuracy of the measurements, the care in taking simultaneous readings, and the stability of the atmosphere.

### 2.4.1. EQUIPMENT

Instruments with a vertical least count of one second or better shall be used, unless otherwise approved by CRGB.

### 2.4.2. PROCEDURES

Vertical angles shall be read simultaneously from each end of a line. To be considered simultaneous, the observations at each end shall start within one minute of each other. A minimum of two sets is required where a set consists of readings taken in the direct and reverse positions. Sets should preferably be taken at different times of day, but shall not be taken during periods when atmospheric conditions are unstable, such as at dawn or dusk. When the period of occupation of a station is limited, it is suggested that one set be observed before the horizontal angles & distances, and a second set after. The start times of each observation set shall be recorded. Instrument heights must be carefully measured and recorded, as well as the distance between stations.

Non-simultaneous trigonometric levelling is not normally used for establishing vertical control.

## 2.5. GENERAL VERTICAL INFORMATION

### 2.5.1. ALTIMETRY AND OTHER HEIGHTING METHODS

Altimetry and other methods of obtaining elevations may be appropriate in unusual circumstances. Special instructions may be issued by CRGB in this case.

### 2.5.2. STATION MARKERS

Station markers for vertical control stations are referred to as benchmarks. All benchmark station details, including the tablet markings and GCM numbers, shall be confirmed by CRGB.

### 2.5.3. HORIZONTAL COORDINATES OF BENCHMARKS

Approximate horizontal coordinates for benchmarks are required to allow plotting positions on index maps, and for entry into the searchable MASCOT database. Horizontal coordinates may be derived by plotting the benchmarks on a 1:50,000 or larger scale map and scaling the NAD83 UTM coordinates, or by using GPS single-point positioning techniques.

A list of station markers and identifiers with their NAD83 UTM coordinates and zone shall be submitted with the survey returns. Coordinates of benchmarks shall be listed in the station definition records in the abstracts of observations.

#### 2.5.4. SURVEY RETURNS FOR VERTICAL CONTROL

Survey returns specifically required for vertical spirit-levelling projects:

- Report (see Section 4.2)
- Field notes (see Section 4.3)
- Differential levelling diagram (see Section 4.4.1)
- Abstracts of observations (see Section 4.3.2 & Section 4.3.4)
- Station descriptions and diagrams (see Section 4.5)
- Computations and adjustments (see Section 4.6)
- List of benchmark unique identifiers (tablet markings) and GCM numbers with corresponding approximate coordinates (see Section 2.5.3)

# 3. HORIZONTAL CONTROL SURVEYS

Horizontal control networks are typically commissioned to extend, densify and/or strengthen the existing provincial control network. The CRGB mandate is to build a stronger GPS-based provincial reference system, with less emphasis on the maintenance and expansion of the existing physical monument control system. New survey control areas (typically within municipalities) are currently planned with a less dense grid of new monuments (800m or more spacing). Traditional network design considerations such as station intervisibility and network geometry are being replaced by the need to provide for good GPS horizons at the new monuments.

Although the CRGB mandate supports the use of GPS to conduct new survey control projects, it is recognized that GPS methods do have limitations (e.g. horizon obstructions, reflective environment creating signal multipath, and attainable precision on short baselines). It is also recognized that many surveyors throughout the province still prefer to conduct daily operations using traditional conventional survey techniques. Conventional survey methods may still be used to establish horizontal control provided that it is shown that the required accuracy standards can be met, and that sufficient observations are made to provide an independent check on each position determination.

Traditionally, a variety of conventional survey methods have been used to establish new survey control (e.g. triangulation, trilateration, traverse, intersection, resection, etc.). Currently most conventional control surveys are conducted by closed traverse methods using 'Total Station' survey equipment.

This Section contains accuracy standards, specifications, and guidelines for establishing horizontal control using conventional surveying techniques. The primary focus is placed on network design characteristics and observation procedures used for projects conducted within a Municipal Geo-Spatial Reference (MGSR) area. Although the guide is specific to this type of control survey, the procedures and methodologies outlined here can be used for any horizontal control projects requiring similar accuracy standards.

## *3.1. ACCURACY STANDARD*

The *Local Accuracy* of a control point is a value that represents the uncertainty in the coordinates relative to the coordinates of adjacent control points, at the 95% confidence level. The *Local Accuracy* is an average of the 95% relative error ellipses to adjacent stations, resulting from a minimally-constrained Least Squares (LS) adjustment. This accuracy measure can be computed by the surveyor to confirm that the survey measurements have met the horizontal accuracy specifications. An example could be a horizontal survey specified with a *Local Accuracy* in the 0.02m class. <u>In this case all computed *Local Accuracy* values would have to be at or below 0.02m in order to meet the contract accuracy specifications.</u>

The *Network Accuracy* of a control point is a value that represents the uncertainty in the coordinates of the control point with respect to the provincial geo-reference system framework, at the 95% confidence level. The reported *Network Accuracy* of a control point is computed from a constrained network LS adjustment with appropriate weighting assigned to the existing provincial control station coordinates.

The 95% horizontal station error ellipses determine the *Network Accuracy* of a control point. Note that this value is affected by the quality of the existing control stations. The final constrained LS network adjustment for provincial horizontal control surveys is normally carried out by CRGB, as they have access to complete information for correct weighting of the existing control stations.

Conventional survey measurement errors can be classified into two groups: those proportional to distance (usually expressed as a Part per Million or PPM of the separation distance), and those independent of distance (i.e. they are constant). For short distances the second group is dominant, while for long distances the first group becomes dominant. Surveyors must be aware of the impact of these conventional errors when designing observations to meet a specific *Local Accuracy*. Table 3.1 indicates the impact of conventional survey errors at various station separation distances.

*Local Accuracy* class required for MGSR survey projects conducted using conventional survey techniques are:

| Line Distance | Horizontal *Local Accuracy* class |
|---|---|
| Lines < 2km | 0.02m |
| Lines > 2km | 0.05m |

The standard deviations of conventional survey observations directly affect the size of the resulting relative error ellipses, and therefore also the computed *Local Accuracy*. The following Sections provide guidance as to the minimum instrument specifications required in order to obtain specific *Local Accuracy* classes at varying distances. If different observing procedures and equipment specifications are proposed, they must first be approved by CRGB following a rigorous pre-analysis showing that they can meet the required accuracy.

## 3.2. CONVENTIONAL SURVEYS – GENERAL

### 3.2.1. NETWORK DESIGN

The importance of an effective survey network design cannot be too strongly emphasized. The size and shape of the 95% confidence regions is dependent not only on the accuracy of the field measurements, but also on the configuration of the network and the location of the constraining control stations within the network. In order to ensure that a particular accuracy class will be obtained before commencing the field work, it is advisable to test the proposed network design and measuring techniques in an adjustment simulation using apriori estimates for the proposed measurements. It is suggested that a 20% contingency factor should be added to the equipment specifications to ensure the proposed measuring techniques are suitable for obtaining the required accuracy.

The following basic principles shall apply to the design of a conventional control network traverses:

a) Scale and orientation for horizontal control survey networks should be derived from ties to existing survey stations of the same or higher *Network Accuracy* as the project *Network Accuracy*.
b) Long and narrow patterns shall be avoided in the network design.
c) A traverse shall be as straight as possible. Where practical, all stations shall be within 1/4 D of the line joining the controlling end stations, where D is the distance between controlling end stations.
d) Stations shall be as evenly spaced as possible. Where practical, no traverse line should differ in length by more than 50% from the average length of all the lines. The ratio of the longest length to the shortest shall, where practical, not be greater than 3 to 1.
e) All neighbouring stations in a survey network shall be connected by direct measurement. In urban areas where this is impractical and a traverse must be employed, every effort shall be made to ensure that intersecting traverses are established to connect every third or fourth station in the traverse.
f) No traverse station should be closer to an existing control station not forming part of the traverse, than the average distance between the stations in the traverse.
g) A traverse shall be oriented at each terminal station by sighting on at least one other existing control station of the same or higher accuracy class, and which is part of the same network as the terminal station.
h) The analysis of the survey design and the desired accuracy of positions should dictate the minimum distance between stations, however, as a general rule, the length of a line in a traverse should not be less than two hundred metres.
i) To facilitate future use of traverse stations, each marked station shall be intervisible with at least one other marked station in the traverse network.
j) The spacing of higher accuracy class control stations should generally be greater than that of lower accuracy class stations. Higher accuracy class control shall always be established at a sufficient density to govern the establishment of lower accuracy classes.
k) Eccentric stations should not normally be used. Targets or lights may be set out on-line between stations but should not be set out off-line so that a correction to the observed direction would be required. Distances shall be measured directly between stations. There will be occasions when, due to the location of existing control stations, it is necessary to use an eccentric station. In these cases special care shall be taken in measuring the eccentricity to ensure redundancy and accuracy of measurements.

### 3.2.2. RECONNAISSANCE

The procedures and methods employed during the design and reconnaissance phase of a conventional control survey can significantly influence the cost and accuracy of the survey as well as the usefulness, permanence and stability of the monuments established.

Since there are a large number of variables in each project, no rigid rules are given for carrying out the reconnaissance. The following procedural guidelines are intended to assist the surveyor in conducting this phase of the work:

a) It is advisable to start reconnaissance with a study of the most up-to-date maps available. The proposed locations of all new stations selected on the maps together with all existing control stations to be used in the survey should be inspected on the ground.
b) Intervisibility between stations, where a clear line of sight is required, should be verified on the ground where possible. Lines of sight should clear all obstructions by at least 1m horizontally and by at least 1m vertically. The use of towers should be kept to a minimum. Where use of towers cannot be avoided, favourable locations for their erection should be selected during the reconnaissance. Lines of sight should not pass through wire fences, nor heated air from chimneys, air conditioners, etc.
c) It is advisable to plot the control network on a map of suitable scale and to indicate all measurements proposed to be made as well as the approximate elevation of each station.
d) Horizontal control survey stations should be located on prominent sites where visibility is unimpeded. Sites should be chosen which are not likely to be disturbed by future development. Monuments should be placed on other than privately owned lands where it is possible to do so without significantly weakening the strength of the network design, or incurring unreasonable hardship and cost.
e) Tact and good manners are essential when dealing with the public. Where it is necessary to place a monument on private land no effort should be spared in informing the owners of the land involved, of the purpose and usefulness of the work being done and of the importance of the stability and security of control monuments.

### 3.2.3. MEASUREMENT GUIDELINES FOR CONVENTIONAL OBSERVATIONS

Survey networks must be designed to satisfy the accuracy requirements in accordance with Section 3.1. The measurement guidelines in Table 3.1 are based on experience and on the results of computer simulation studies of some simple, idealized networks. This table should be considered the minimum requirements necessary to maintain the required standards. Due to the effects of network configurations and possible systematic or gross errors, there is no guarantee that using the recommended measurement guidelines will always result in meeting required accuracy specifications. A minimally constrained LS adjustment of the conventional data is the only way to confirm that the *Local Accuracy* class specifications were met for each project. Specific observation procedures and recommended equipment specifications are detailed in the following Sections.

| STN to STN Distance (m) | Accuracy Class (m) | Directions | | | Distances |
|---|---|---|---|---|---|
| | | # of Sets | St Dev. of Set | Least Count of Instrument | EDM Specification |
| | | | | | |
| 0 - 500 | 0.02 | 4 | 5" | 1" | 5mm + 5ppm |
| | | | | | |
| 500 - 1000 | 0.02 | 3 | 3" | 1" | 3mm + 3ppm |
| | | | | | |
| 1000 - 1500 | 0.02 | 3 | 3" | 1" | 2mm + 2ppm |
| | | | | | |
| 1500 - 2000 | 0.02 | 3 | 2" | 1" | 2mm + 2ppm |
| | 0.02 | 3 | 3" | 1" | 1mm + 1ppm |
| | | | | | |
| 2000 - 3000 | 0.05 | 3 | 3" | 1" | 3mm + 3ppm |
| | | | | | |

**Table 1: Conventional Measurement Guidelines**

#### *3.2.3.1 Horizontal Angle Measurement*

There are several methods of measuring horizontal angles, however, for MGSR control survey projects only the direction method is to be used. In this method, at each instrument station, the directions to other stations are measured clockwise from one of the lines which are considered as the initial line. The angle at a station between the lines to any two points is the difference between the directions to them.

**Terminology**

An observation is the horizontal circle reading for one pointing of the instrument.

A set using a conventional instrument is a series of observations on two or more targets such that:
a) the setting of the horizontal circle remains constant, and
b) an observation is made on each target successively in clockwise order, beginning and ending with an initial line, then with the instrument on reverse clamp, an observation is made on each target successively in counter clockwise order beginning with the target last sighted.

A measurement is a specified minimum number of sets taken consecutively during a particular period with little or no time lapse between sets and such that the setting of the horizontal circle is changed for each set to distribute the readings evenly around the circle.

For all conventional optical instruments the horizontal circle and micrometer settings must be varied between sets to minimize the effects of graduation errors.

Measurements shall be checked immediately to ensure that the specified standard deviation has been achieved. If not achieved, then steps shall be taken to determine the reason and to correct the fault and additional observations shall be taken. Rejected observations shall be crossed out with an oblique line that does not obscure the figures.

Instruments with a least count of one arc second shall be used for all MGSR surveys.

#### 3.2.3.2 Distance Measurement

The EDM specifications given in Table 1 are the maximum allowable constant plus ppm values based on the manufacturer's equipment specifications, and the repeatability of the observations.

EDM distance measurements are to be made in accordance with the manufacturer's procedures, and in the same manner as during the baseline calibrations.

Meteorological observations near the EDM or the reflector are required when measuring short (<800m) lines at the time of distance measurement. Lines >800m distance require meteorological observations near *both* the EDM and the reflector, with the mean values being used for refractive index corrections. Temperatures shall be observed with an accuracy of 1 degree Celsius, and atmospheric pressure with an accuracy of 3mb. If the EDM is based on microwave emissions, the humidity must be accurately measured and recorded. All meteorological observations shall be sampled until they remain stable (this may take several minutes). Meteorological observations shall be recorded in the manual field notes, even if they are recorded electronically. The refractive index correction can be applied automatically within the EDM, or it can be computed and applied manually later. However, this methodology must be the same as used during the baseline calibration, and it must be recorded in the manual field notes.

The EDM system constant and scale (from a recent calibration) shall be recorded in the field notes. These EDM calibration corrections can be applied automatically within the EDM, or they can be computed and applied manually later, but this methodology must be the same as used during the baseline calibration, and it must be recorded in the manual field notes.

The slope distance and vertical angle must be independently measured and recorded at least twice in each direction (reversing the telescope between measurements). The distances and vertical angles must agree within the equipment specifications. Instrument and reflector heights must be carefully measured and recorded with an accuracy of <5mm for each setup. After measuring in the first direction, the EDM and reflector are to be exchanged for the second set of measurements in the opposite direction. The averaged reduced distance in each direction must agree within the equipment specifications. The reduced distances for this comparison can be either horizontal or mark-to-mark. Note that reduced mark-to-mark distances are required for final submission to CRGB.

#### 3.2.3.3 Vertical Angle Measurement

Vertical angles are required to reduce the measured slope distances (see Section 3.2.3.2).

Elevations shall be determined for all occupied horizontal control stations. If accurate elevations from differential spirit levelling are not necessary, or impractical, elevations may be determined by trigonometric levelling using the method of simultaneous reciprocal vertical angles (see Section 2.4). CRGB must be consulted before trigonometric levelling is used.

#### *3.2.3.4 Measurement Checks*

Horizontal angles (directions) can be checked by calculating the angular misclosures of triangles and traverses. Inter-connected traverses provide a number of closed loops by which angles may be checked.

Distances shall be checked by comparing the difference in the reduced horizontal distance observed from either end of a control line. Horizontal traverse closures can be used for blunder detection prior to the adjustment of data.

#### *3.2.3.5 Equipment Checks*

Tripods should be checked for stability. Heavy wooden tripods are recommended, especially under windy conditions. The stability of the instrument and target tripod setups should be checked periodically during observations by monitoring the level bubbles and optical plummets. If either the instrument or target tripods are significantly out of level or off-center, all observations at this setup must be repeated. Under sunny conditions it may be necessary to shade the tripod in order to avoid bubble displacements due to expansion of the tripod assembly or sinking of the legs.

Tribrachs with optical/laser plummets shall be tested for vertical alignment at least once every two weeks. The centering accuracy of the tribrach bubble/plummet shall be <2mm. Tribrachs with rotating plummets/plate bubbles have better accuracy, and are easier to check than tribrachs with fixed plummets and circular bubbles.

EDM instruments shall be calibrated on a precise base line to determine the system constant and scale factor. This is required for any EDM / reflector combination, and is to be submitted to CRGB prior to starting a project. Please contact CRGB for further information regarding EDM instrumentation calibration.

Projects with durations longer than two weeks shall include 2 EDM calibrations performed within two weeks before and after the project. Projects with a shorter duration require only a single calibration performed before the project.

#### *3.2.3.6 COMPUTATIONS*

Sufficient field checks and computations shall be carried out by the project supervisor to ensure that the survey observations meet the accuracy specifications, and that there are no blunders or systematic errors. This may include a minimally-constrained LS adjustment. The final constrained LS adjustment of the control network will be performed by CRGB.

### 3.2.4. STATION MARKERS

All MGSR station marker details, including the tablet markings and GCM numbers, will be confirmed by CRGB.

### 3.2.5. STATION REFERENCING

Established control stations require at least 3 reference distance measurements to near-by durable reference objects (e.g. utility poles, fire hydrants, catch basins, etc). This referencing information will be shown on the ENV 2052 station diagrams to be submitted.

### 3.2.6. SURVEY RETURNS FOR CONVENTIONAL HORIZONTAL CONTROL

Survey returns specifically required for conventional horizontal control projects:

- Report (see Section 4.2)
- Field Notes (see Section 4.3)
- Schematic Diagrams (see Section 4.4)
- Abstracts of Observations (see Section 4.3.2 & Section 4.3.4)
- Station Description and Diagram Cards (see Section 4.5)
- List of Stations by unique identifier (tablet marking), with GCM numbers, preliminary coordinates, preliminary elevations, and type of survey marker
- System calibration constant and scale factor for each EDM / reflector

# 4. SURVEY RETURNS - GENERAL

This Section details the requirements for survey returns. Some or all of the items described in this Section will be included in any particular project. Required items are listed in the Section pertaining to each particular type of survey.

All horizontal and vertical control projects conducted for CRGB will be assigned a unique MASCOT project number that must be used in all correspondence relating to the project. Observation data provided to CRGB in MASCOT format must contain the unique MASCOT project number in the observation header line.

All new horizontal control stations, benchmarks, traverse hubs and temporary benchmarks will be assigned unique Geodetic Control Monument (GCM) numbers. These GCM numbers will be used for all observation data submissions, field abstracts and final returns required for submission to the MASCOT database.

Any digital submissions must be in a format readable by a PC. Files may be submitted on DVD media, external hard disks, or zipped email attachments. Consult CRGB for other methods of file submissions.

## 4.1. UNITS OF MEASURE

Units of linear measurements shown on station diagrams and schematics shall be in metres. Linear measurements may be made in units other than metres but, in this case, the units of length shall be shown on every page of field notes and other documents where they appear.

Temperature may be recorded in degrees Celsius. The units shall be shown beside each observation or group of observations.

Atmospheric pressure may be recorded in units of millibars or millimetres of mercury. The units shall be shown beside each observation or group of observations.

In cases where an instrument measures in non-SI units, the conversion factor to obtain SI units shall be included in the report.

## 4.2. REPORT

A report shall accompany survey returns for every project. The report shall include from the list that follows all those items pertaining to the survey.

- Project name and MASCOT project number
- Purpose and objectives of the project
- Start date and completion date
- A general description of the methods of survey used

- An explanation of any differences between the plan or proposal and the executed work
- A list of make, model, and serial number of all instruments used
- A list of accessory survey equipment used, e.g. targets, prisms, level rods, etc.
- System constant and scale factor for each EDM instrument, as determined by a baseline calibration
- Conversion factors for non-SI units
- A summary of achievements, including numbers of:
    - previous horizontal control stations occupied
    - previous benchmarks occupied
    - new horizontal control stations established (marked)
    - new benchmarks established
    - unmarked temporary survey stations occupied (TH's)
    - control stations photo-identified
    - photo control stations photo-identified (PHV's - PV's)
    - lengths measured
    - direction sets observed
    - kilometres of differential levelling
- An explanation of problems encountered and any irregularities that may cause difficulties in the computations, adjustment, and analysis of the data
- Owners' names and addresses where permission to enter private property was obtained
- A report on the condition of old stations re-occupied or searched for (see below).

A brief report shall be submitted for each control station searched for and found, or not found, during the course of a survey project. When the station is found, the report shall state the condition of the marker and a new station description and diagram shall be submitted. When the station is not found, the report shall state whether evidence has been found and whether, in the opinion of the surveyor, the station has been destroyed. Marker Condition Report Forms can be obtained from CRGB or online through MASCOT Website.

## 4.3. FIELD NOTES

Original field notes shall be submitted and become the property of CRGB. When measurement data was recorded electronically in the field, a digital copy of the data in its original form must be supplied to CRGB. In some cases an alternate field book output listing may also be required in order to clarify the equipment manufacturer's output format.

### 4.3.1. MANUAL FIELD NOTES

Field notes should be recorded on loose-leaf sheets in the standard size (12cm x 18cm). It is recommended that printed forms be used to promote uniformity, readability, and completeness. Black ink or pencil of hardness 2H or harder shall be used (HB pencil is not acceptable).

All field notes for each occupied station shall be filed together as a unit. The notes for each unit shall have the following order

- station diagrams
- horizontal/direction angles
- vertical angles
- distances

The units shall be filed in ascending order by unique identifier (tablet marker) to form a group.

Differential levels notes can be randomly booked on both sides of a field sheet and cross-referenced in an index.

Each group will be filed in the following order

Group 1 - horizontal control stations (yyHnnnn)
Group 2 - traverse hubs (THnnn)
Group 3 - horizontal photo control (PHVyynnnn)
Group 4 - benchmarks (yyHAnnnn)
Group 5 - vertical photo control (PVyynnnn)
Group 6 - cadastral ties : direct (CDyynnnn)
: offset target (DyyXnnn)
Group 7 - differential levels

A cover page and an index shall be included at the beginning of each book of field notes. Consecutive page numbers should be marked on the top right front side of every sheet after all the notes are in order. The index will consist of a list of all stations in ascending order of unique identifier (tablet marker) and for each station will show the station name, if any, and the page numbers of the observations for which the station was the occupied station.

The cover pages will contain the MASCOT project name and number, and the name and signature of the project supervisor. If more than one book of field notes is submitted they should be numbered using the form: "Book 1 of n", and indexed on each cover page.

Each page shall contain, at the top, the name of observer, name of recorder, instrument model, and instrument serial number for EDM instruments, date, and page number.

All stations used on any project shall have a diagram and description recorded in the field notes for subsequent transcription onto 5” x 8” index cards (see Section 5.3).

Distance observation notes shall indicate the height of instrument and height of reflector or remote instrument. Vertical angle observation notes shall indicate height of instrument, and all height(s) of target(s) or light(s) observed (or set-out for others to observe).

Corrections to distance measurements for EDM constants and meteorological effects shall be recorded and applied in the field notes.

Field notes for spirit levelling tests, and EDM instrument calibrations shall be labelled and included with the returns.

### 4.3.2. ABSTRACTS OF MANUAL FIELD NOTES

All survey observations manually recorded in field notes must be compiled and submitted in ASCII digital and hardcopy MASCOT format. MASCOT format includes header information and observation data specific to each type of observation. A detailed description of the required MASCOT format for various types of conventional observations is provided in Appendix F. MASCOT data files are to use the GCM identifiers for all new and existing control monuments.

### 4.3.3. ELECTRONIC FIELD NOTES

Electronic survey observation data must be submitted in the original manufacturer's proprietary format as downloaded. This format may be difficult to decipher, and therefore most equipment manufacturer's provide software to convert this to a user-defined field book format. Both the original format and the converted field book format files are to be included in the electronic submissions.

The following hardcopy listings must also be included with all electronic file submissions.

- Complete listing of coded raw data as originally electronically recorded.
- Complete listing of decoded raw data formatted in field book format.

Field notes are still required even if the observations are stored electronically. Field notes must include a sketch showing occupied stations, target locations, and the observations conducted at each set-up (see Appendix E). Other information which is not stored in the electronic data collector should be recorded in the manual field notes (e.g. crew names, MASCOT project #, weather conditions, instrument type, etc.).

### 4.3.4. ABSTRACTS OF ELECTRONIC FIELD NOTES

All electronically recorded survey observations must be compiled and submitted in ASCII digital and hardcopy MASCOT format. MASCOT format includes header information and observation data specific to each type of observation. A detailed description of the required MASCOT format for various types of conventional data types is provided in Appendix F. MASCOT data files are to use the GCM identifiers for all new and existing control monuments.

## 4.4. SCHEMATIC DIAGRAMS

Schematic diagrams are required to display the survey design in graphic form and to show the misclosures. Separate diagrams are required for vertical and horizontal control networks. Schematic diagrams shall be plotted to scale in pencil or black ink on a transparent medium. The scale should be that of a map base over which the diagram may be laid and, if possible, the entire project should be drawn on a single sheet. Where it is necessary to use more than one sheet, the sheets should be numbered and a key plan shown on each sheet. Where required for clarity, detail diagrams should be used. Each schematic diagram shall display a legend, scale, north arrow, project name and number, and the name and signature of the project supervisor. Symbols should be used to differentiate between old and new control stations, temporary hubs, benchmarks, and mapping photo control points.

### 4.4.1. DIFFERENTIAL LEVELLING DIAGRAM

Schematic diagram(s) for differential levelling shall show the following:

- approximate station locations using symbols to indicate types of markers
- station unique identifiers (tablet markings)
- station GCM numbers
- lines between stations to indicate survey observations and the approximate routes followed
- differences in elevation with an arrow to indicate the direction of levelling, and the number of turn points
- loop misclosures
- misclosures between controlling benchmarks

Alternatively, a reference table may be used to record the elevation differences and number of turn points.

### 4.4.2. HORIZONTAL CONTROL SURVEY MISCLOSURES DIAGRAM

(see Appendix A)
Schematic diagram(s) to show the final horizontal network shall include the following:

- station locations using symbols to indicate types of markers
- station unique identifiers (tablet markings)
- station GCM numbers
- symbols to indicate the angles and distances that have been measured
- angular misclosure for each closed figure and each traverse closing on control stations
- linear misclosure for each closed figure and each traverse
- elevation misclosures from trigonometric heighting (if applicable)
- misclosures may be printed within the diagram or the closed figures may be labelled and the misclosures shown in tables on the diagram or attached to the diagram

## 4.5. STATION DESCRIPTIONS AND DIAGRAMS

Descriptions and diagrams of all survey control stations are required in both graphical format (described below) and MASCOT digital format (see Appendix D).

Diagrams, approximately to scale, shall be drawn in black ink for all control stations used on any project.

Linework shall be neat and sharp. CAD drawings need to be properly scaled.

Control stations include:
- new and existing monumented survey stations including benchmarks (not including cadastral ties)
- photo control, horizontal and vertical (tablet markings: PHVyynnn)
- photo control, vertical-only (tablet markings: PVyynnn)

Each diagram shall include the following:
- station unique identifier (tablet marking) and GCM number
- Type of monument (if applicable)
- BCGS or NTS map sheet number
- date
- north arrow
- 3 distances to durable reference objects when the control station is monumented
- a general description to assist in locating the station

and if the station is imaged on mapping or supplemental identification photography include:

- roll and frame numbers of supplemental identification or mapping photography on which target or photo identified point is imaged (or digital photograph file names)
- targeting laid out for aerial photography
- a description of the ground conditions around the point, such as height of grass or bushes (ground level is preferred), centre line of road, or corners of buildings, etc.

## 4.6. COMPUTATIONS AND ADJUSTMENTS

Sufficient checks and computations shall be performed to ensure that no blunders exist in the data. The results of these will be shown on the misclosure diagrams (see Section 4.4.2). It is not necessary to include a copy of check computations in the returns.

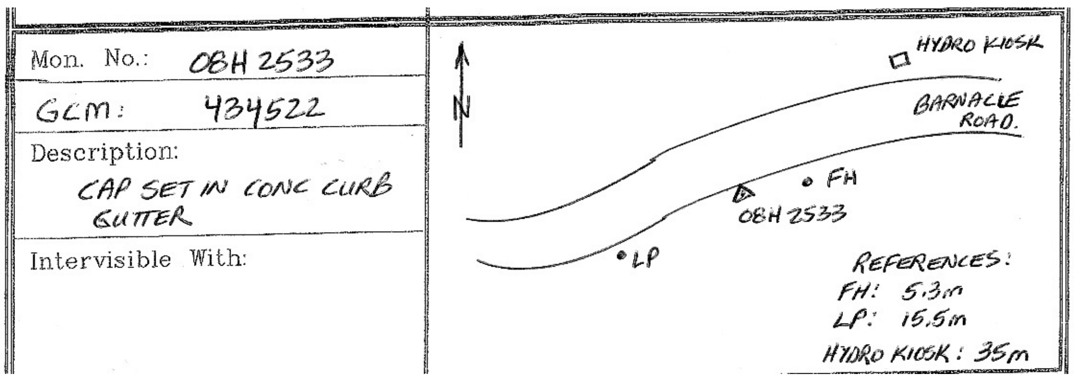
If the project specifies a *Local Accuracy,* a minimally-constrained LS adjustment will be required to compute the 95% relative confidence regions for each station. These confidence regions are then averaged for the adjacent stations to confirm that the *Local Accuracy* specification has been met.

Projects that require computation of preliminary coordinates shall include these values in the returns.

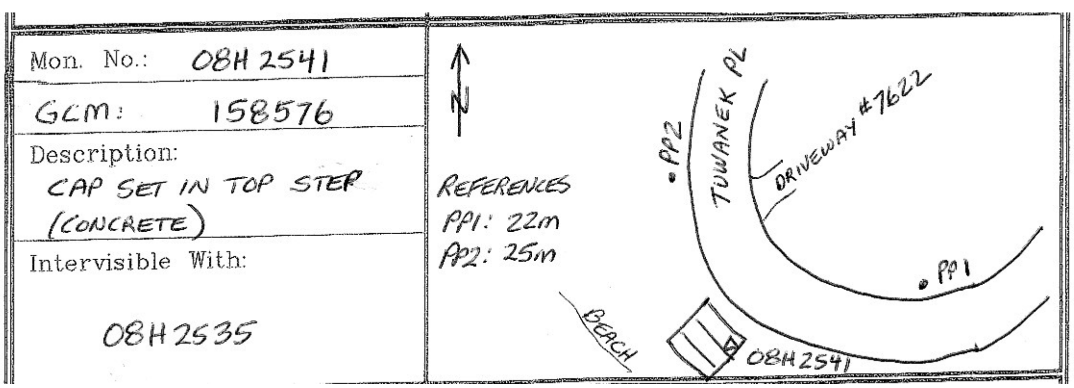
# Appendix A

## Horizontal and/or Vertical Monument Location Sketches

**Sample 1**



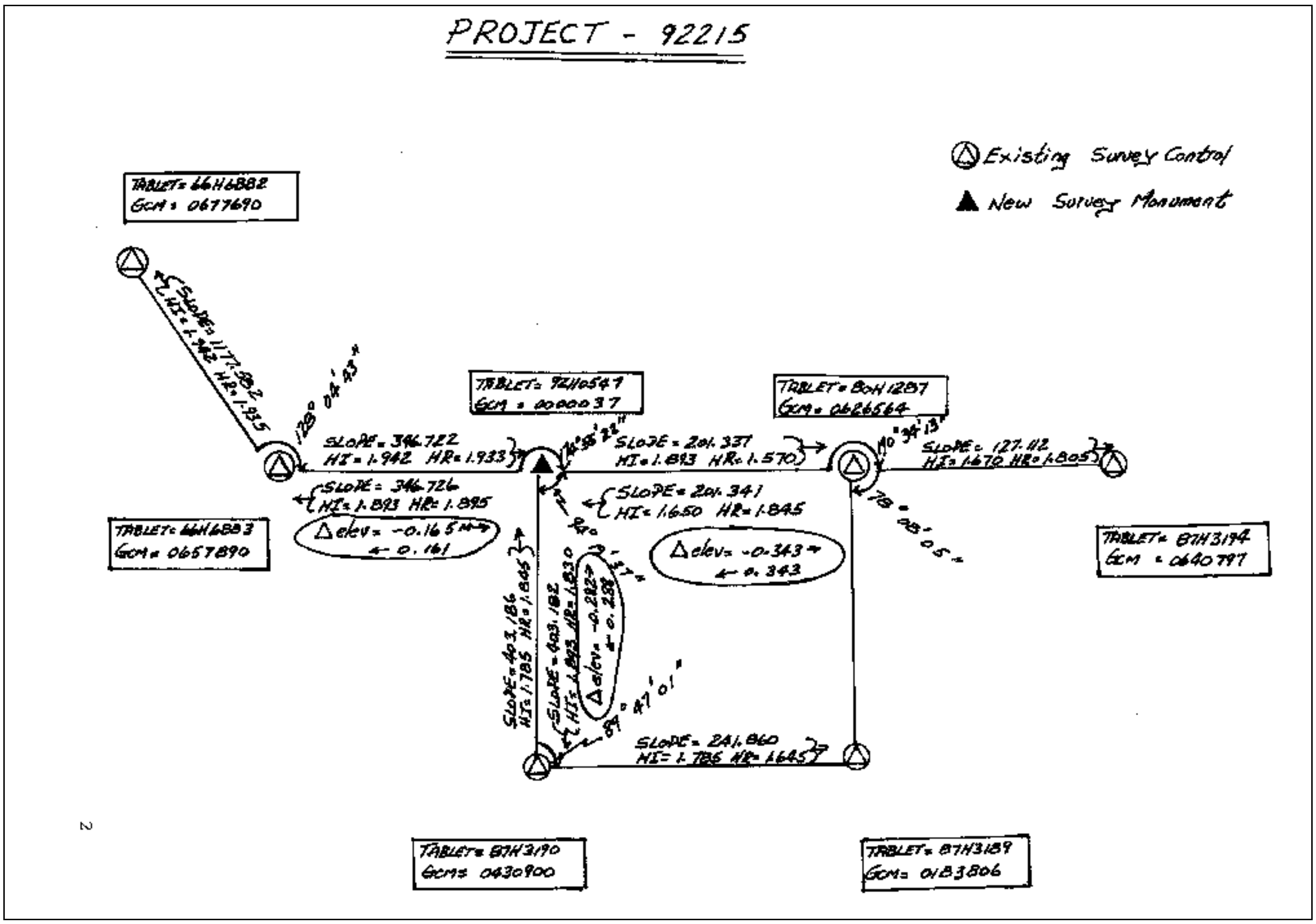

**Sample 2**



# Appendix B

## Field Note Samples

### a) Sketch of Survey



# Appendix C

## Sample Field Note Sheets

### a) Field Notes:

| | | | |
|---|---|---|---|
| Page: | | Observer: | |
| Project # : | | Recorder: | |
| Weather: | | Date: | |
| | | | |
| From (GCM or BM) | | To (GCM or BM) | |
| | | | |
| BS #1 | FS #1 | BS #2 | FS #2 |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| Elev. Diff. #1 | | Elev. Diff. #2 | |
| | | | |
| Mean Elev. Diff. | | Enter 'Y' if continues on next page | |
| For Branch Use Only | | | |
| Header Ref # | | OBS.# | |
| | | | |
| **CRGB, GeoBC** | | | |
| | | | |

## b) Level header

| Level Header | | |
|---|---|---|
| | | |
| Project Number: | | |
| Agency: | | |
| Surveyor: | | |
| Level make/model: | | |
| Level serial # : | | |
| Invar rod #1/#2 type : | | |
| Invar rod #1/#2 units : | | |
| | | |
| Parallel plate | Y | N |
| | | |
| **For branch use only** | | |
| Agency code: | | |
| Surveyor code: | | |
| Level code: | | |
| Level serial # code: | | |
| Conversion factor (x): | | |
| Header reference number: | | |
| Note: Observations contained in the following pages were obtained by the surveyor and the survey system indicated on this header. | | |

# Appendix D

## MASCOT & GHOST Formats

Please contact CRGB for more samples and explanation with MASCOT & GHOST formats. Below samples are provided for reference purposes only.

### a) Distance Observation Records

This record is used to establish a distance observation.

```
COLUMN    CONTENT

  1-2     Blank
    3     Code : 2
  4-6     Type used to identify the record with a SIGMA-DISTANCE
          record
 7-15     Number used to identify the observation as
          originating from the station as identified in the
          STAtion DATA file
 16-30    Originating station name
 31-39    Number used to identify the observation as targeting
          on the station as identified in the STATION DATA file
 40-54    Targeting station name
    55    Sea level indicator
                  Blank:  sea level distance (GHOST reduces it to a
                          Marker-to-marker distance using the
                          elevations provided on the coordinate
                          records)
                  Non blank: marker-to-marker distance
 56-70   Distance observation in meters
 71-80   Standard deviation of the observation in centimetres
          (Used if the type does not match the previous sigma type
          from the code 52 record)
```

### b) Direction and Azimuth Observation Records

These records are used to establish a direction or an azimuth observation.

```
COLUMN    CONTENT

  1-2     Blank
    3     Code    1 :  direction
                  3 :  azimuth
  4-6     Type used to identify the record with
                 51 :  a SIGMA-DIRECTION set
                 53 :  a SIGMA-AZIMUTH group record
  7-15    Number used to identify the observation as
          originating from the station as identified in the
          STAtion DATA file
 16-30    Originating station name
```

```
       31-39    Number used to identify the observation as targeting
                on the station as identified in the STATION DATA file
       40-54    Targeting station name
          55     Azimuth origin indicator (for azimuths only)
                       North : blank, N, +
                       South : S, -
       56-58    Observation degrees
       59-61    Observation minutes
       62-70    Observation seconds
       71-80    Standard deviation of the observation in seconds
(Used if the type does not match the sigma type on the previous code 51 or
code 53 record)
```

### c) Computation of SDA for Direction Observations

| Instrument | Instrument Code | SDA (sec) |
|---|---|---|
| First order (Wild T3 or equivalent) | 51Fxx | 0.6 x sqrt(16/N) |
| Second order (Wild T2 or equivalent) | 51Sxx | 2.0 x sqrt(8/N) |
| Third order (Wild T1 or equivalent) | 51Txx | 7.0 x sqrt(3/N) |
| After 1970: With Geodetic Survey new observing procedures: | | |
| First order (Wild T3 or equivalent) | 51Fxx | 0.6 x sqrt(24/N) |
| Second order (Wild T2 or equivalent) | 51Sxx | 2.0 x sqrt(6/N) |

Note: xx = number of sets
N = number of sets

Examples of instrument codes:

51F16, 51F12, 51F08, ...
51S08, 51S06, 51S04, ...
51T06, 51T03, 51T01, ...

## d) MASCOT Levels

```
 columns   1         2         3         4         5
12345678901234567890123456789012345678901234567890

199009SYY0010603L30V0110000001
2990606    931584    587360
3          1.962     1.606     1.962     1.606
3          1.480     0.860     1.480     0.860
4          0.976         01    001
2990606    587360    247128
3          0.748     1.979     0.748     1.979
3          0.625     1.375     0.625     1.375
4          -1.981        01    002
```

| | | |
|---|---|---|
| Line 1 Cols | 2- 6 | Mascot Project Number |
| | 7- 9 | Rod Type (SYY) |
| | 10-12 | Survey Company / Municipality |
| | 13-16 | Surveyor |
| | 17-19 | Level Type Code (leave blank) |
| | 20-22 | Level Serial Number Code (leave blank) |
| | 23-30 | Conversion coding (10000001) |
| Line 2 | 2-7 | Date of observation (yymmdd) |
| | 8-9 | Blank |
| | 10-16 | GCM 'Backsight' |
| | 17-19 | Blank |
| | 20-26 | GCM 'To' |
| Line 3 | 2-10 | Blank |
| | 11-20 | Backsight one |
| | 21-30 | Foresight one |
| | 31-40 | Backsight two |
| | 41-50 | Foresight two |
| Line 4 | 2-10 | Blank |
| | 11-20 | Mean Difference in Elevation |
| | 21-25 | Blank |
| | 26-27 | Header Number (01) |
| | 28-29 | Blank |
| | 30-32 | Observation Number (001, 002…..) |