Toitu te whenua
Land Information
New Zealand

Specifications for Geodetic Control Survey

Version 2.3
Customer Services

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Contents

Foreword

Section 3(c) of the Cadastral Survey Act 2002 defines a purpose of the Act to:

> *provide for a national geodetic system and a national survey control system to be maintained.*

These specifications form part of a set of specifications developed by Customer Services Geodetic, Land Information New Zealand, to contribute to achieving this purpose. They relate to the provision of geodetic control survey to support the geodetic programme as required by the Cadastral Survey Act 2002 sec 7(1)(a) and (b).

This specification is a major revision of the previous Geodetic Control Survey specification, version 1.3 published in November 2006.

Related Standards, Specifications

- Accuracy Standards for Geodetic Surveys: Office of the Surveyor-General 2003
- Specifications for Geodetic Physical Network Version 2.3: Customer Services 2009
- Specifications for Geodetic Contract Deliverables Version 1.2: Customer Services 2009
- Surveyor-General's Rules for Cadastral Survey 2002/2

Version 2.0	**Released 31 July 2007**
Version 2.1	Section 1 "Introduction" simplified to remove references to separate geodetic networks.
Version 2.2	Appendix 1. New bullet point added re relative accuracy to nearby control Appendix 2. Section 2, version of SNAP updated. Table A6: Horizontal and vertical absolute accuracies qualified.
Version 2.3	Section 3. Re-written to provide guidelines for choosing marks in development and re-establishment areas. Section 5.2. Amended requirements for connections to neighbouring marks of the same order as the survey. Sections 5.5 and 5.6. Additional sections outlining new requirements for providing photos and mark and site details. Appendix 2. Section 2, version of SNAP updated.

General Manager
Customer Services
Land Information NZ
P O Box 5501
Wellington
Phone: 0-4-460 0110
Fax: 0-4-460 0112
Internet http://www.linz.govt.nz/

SPECIFICATIONS FOR GEODETIC CONTROL SURVEY

1 Introduction

1.1 *Scope of this Specification*

This specification covers the survey requirements for the provision of New Zealand Geodetic Datum 2000 (NZGD2000) geodetic control. The maintenance of the physical network is covered in the Specifications for Geodetic Physical Network.

2 General Requirements

2.1 *Site Access and Safety*

Permission to enter private land should be obtained from the landowner/occupier prior to any access to the site for carrying out control survey work. Details of the land owner/occupier may be available from the Geodetic Database (see http://www.linz.govt.nz/geodetic/geodetic-database/index.aspx).

Contractors must be fully aware of, and at all times exercise their responsibilities and obligations under, the Health and Safety in Employment Act 1992.

2.2 *Notification of Work being Undertaken*

Customer Services Geodetic shall be notified of any work that is likely to affect users of the site, mark and/or beacon during the course of the survey, such as beacon removal for a period (greater than several hours) while surveys are carried out.

Note: If a beacon is removed from a mark it should be laid on its side to avoid possible confusion if observed to while out of position.

3 Marks to be used for NZGD2000 Control

Customer Services Geodetic will identify specific marks or general mark locations required for geodetic control survey and these will be supplied separate to these specifications.

Where practical any marks should be selected such that they provide visibility to other NZGD2000 geodetic control marks to enable their use for conventional surveys.

3.1 *Guidelines for Choosing Marks for Survey Control*

This section contains information about factors to take into account when choosing marks to survey for geodetic control. Selected areas or Selected marks may be defined by LINZ as being part of a:

a) Development Area – Areas with geodetic control at an insufficient density for current or future land development requirements.

b) Re-establishment Area – Areas with low order (5a or lower) geodetic control which requires resurvey, or reestablishment of marks in more suitable locations. Note that 5a marks are to be treated as low order marks and should be considered for re-survey where they are appropriately located.

3.1.1 *Choosing Marks in a Development Area*

The following is a list of marks considered suitable for upgrading to 5th Order NZGD2000 standards, in order of preference:

a) High order (1st, 2nd, 3rd) NZGD49 trigs with easy access/good visibility (good for calculating transformation parameters, getting NZGD2000 bearing origins).

b) Bench marks and traverse marks on SO plans, with 8th Order NZGD2000 coordinates (LINZ can capture the plans for further 5th Order upgrades).

c) Marks from which NZGD2000 trigs can be seen (helps with obtaining an NZGD2000 bearing origin).

d) Marks already in Landonline (assists future cadastral upgrades since marks are already connected to the cadastre in Landonline).

e) Any other witness or traverse mark shown on an approved cadastral plan.

3.1.1.1 Points to consider in choosing mark density

Generally no explicit mark density is stated. Choose an appropriate density, which may vary throughout the selected area, taking into account the following factors:

- parcel size
- amount of development (as indicated by survey plans)
- minimum requirements (2 marks per township, enables SDC to be generated and provides a minimal level of redundancy)
- local knowledge about development within the next few years
- location of existing NZGD2000 geodetic marks (5th Order and higher)
- any specific guidance given in the 'Notes' provided by LINZ

3.1.2 *Choosing Marks in a Re-establishment Area*

The following is a list of marks considered suitable for resurveying or upgrading to 5th Order NZGD2000 standards:

a) Compulsory attributes:
   - Existing 5a marks (alternatively, a mark with a direct connection to 5a may be used if no 5a marks in the vicinity meet the other criteria).
   - Have a defined reference point for both horizontal and vertical observations (eg dimple, nail or pin).
   - Practical for GNSS survey observations.
   - Likely to remain stable and reliable.
   - Located where safe access can be readily gained (minimal traffic management). Marks in live traffic lanes are not considered appropriate, even on low-volume roads.

b) Desirable attributes:
   - Located to enable the collection of conventional survey observations to adjacent geodetic and cadastral marks.
   - Clearly identifiable as a geodetic mark (eg mushroom plaque, id plaque or cast iron cover). The main purpose of this requirement is to reduce the chance of the mark being accidentally destroyed.
   - Not buried (or if so, identifiable with a metal detector and readily accessible).

3.1.2.1 Points to consider in choosing mark density

Marks should be chosen such that as many boundary points as possible within the selected area are within 200m of a control mark. The location of existing 0-5b marks must be taken into account.

3.2 *Use of Existing Marks*

Every effort shall be made by the Contractor to upgrade existing NZGD49 geodetic control marks or cadastral survey marks to NZGD2000 in preference to the installation of new marks.

Any maintenance of the existing mark and/or its associated protection structures shall comply with the requirements of the Specifications for Geodetic Physical Network.

As part of the survey, all existing marks to be upgraded will need to be proved reliable in terms of Section 5.4.1.

3.3 *Use of New Marks*

Where a mark is required in a location where no suitable existing marks are available, the Contractor shall install a new mark.

The construction of the new mark and/or any associated protection structures shall comply with the requirements of the Specifications for Geodetic Physical Network.

4 Geodetic Codes and Mark Naming

4.1 *Geodetic Codes*

Each mark is to be assigned a unique four-character geodetic code supplied by Customer Services Geodetic.

If a mark has an existing geodetic code, its existing code shall be used.

4.2 *Names for Existing Marks*

Where an existing geodetic survey mark is selected, its existing identification as shown in the geodetic database shall be used, except that it may be necessary to change the case of the name. Names should be entirely uppercase, except where a Survey District forms part of the name, in which case the Survey District is to be enclosed in brackets and be in sentence case. The following examples should be followed:

- for an existing geodetic mark referred to as “Dingle Peak”, the case should be changed to “DINGLE PEAK”;
- for an existing geodetic mark referred to as “B (MAROTIRI SD)”, the case should be changed to “B (Marotiri SD)”.

For a cadastral mark that is upgraded, its existing identification along with its plan number shall be used. Note that the use of “OLD” (eg as in OIT I) to prefix a mark shall not be used. The following examples should be followed:

- for a mark off a plan referred to as “OIT IV DP 2532”, “IT IV DP 2532” shall be used;
- for a mark (eg “IT III DP 2398”) that has been renamed (eg “SS 23 SO 2865”) the more recent name, “SS 23 SO 2865”, shall be used;

For a mark that has an alternative name (eg a geographical location) this name shall be included in the contract deliverables.

There must be one space between each element of the name (eg. IT XI DP 2345).

4.3 *Names for New Order 2000 Marks*

New marks shall be named by LINZ or in accordance with instructions issued by LINZ.

5 Survey Requirements

5.1 *Method of Survey*

The method of survey used must be sufficient to meet the accuracy requirements detailed in this specification (see section 5.4).

Survey observations shall be undertaken in accordance with good survey practice (refer to Appendix 1) and sufficient observations must be made to test for any potential survey errors, such as plumbing errors or where GNSS is used multipath errors, and to ensure that the survey accuracy requirements can be tested and proven.

5.2 *Network Configuration and Connections*

Mark(s) in a new network must be connected to a minimum of 2 existing NZGD2000 marks of a **higher** accuracy order in a way that absolute coordinate accuracy tests can be applied and proven (refer to Appendix 2). The survey network shall be designed in such a way that **ALL** observations can be checked by a network adjustment and that the relative accuracy to other geodetic control marks is maintained.

Unless specifically stated, LINZ does not require additional connections to neighbouring marks which are the same order as the survey.

5.3 *Field Notes*

The Contractor shall retain survey field notes for 2 years from the date of survey.

5.4 *Survey Accuracy*

The accuracy requirements for provision of geodetic control shall meet the following standards for class and order:

Table 2: Standards for Class 2000 Surveys

Order	Horizontal Accuracy and Class			Height Accuracy and Class		
	Class	Constant - e (mm)	Line length error - p (ppm)	Class	Constant - e (mm)	Line length error – p (ppm)
0	B10	3	0.01	B30	3	0.03
2	M1	3	1	M3	10	3
5	M30	10	30	M100	10	100

Note: Although p is a dimensionless quantity, when it is used in the formula below it has the effect of being a ppm accuracy standard, e.g. when p=1 this represents a distance dependent error of 1:1,000,000 or 1 part per million.

The accuracy for an observed vector is determined by:

$$95\%\ \text{confidence limit} = \pm \sqrt{e^2 + (\text{distance (km)} \times p)^2} \quad \text{mm}$$

Guidelines for Assessing Data Accuracy are provided in Appendix 2 attached to these specifications.

5.4.1 *Mark Reliability Checks*

The Contractor is responsible for ensuring that all existing marks selected as proposed NZGD2000 marks have been correctly identified and proven reliable. For NZGD49 trigs and rural bench marks a visual inspection is sufficient. Other existing marks, including cadastral marks, are considered correctly identified and reliable if both of the following conditions are met:

1) a cadastral survey origin is observed, consisting of at least 3 marks including the existing mark selected as a proposed NZGD2000 mark, that complies with all of Rule 26 of the Surveyor-General's Rules for Cadastral Survey 2002/2 and;

2) where the Surveyor-General's Rules for Cadastral Survey 2002/2 would allow the difference between each newly observed vector forming part of the cadastral survey origin and the equivalent adopted or calculated vector with which it is compared to exceed 0.05m, the maximum difference allowed is 0.05m.

The Mark Reliability Check data shall be supplied according to the Specifications for Geodetic Contract Deliverables.

It is recognised that in some circumstances sufficient marks cannot be found or good survey practice cannot be followed (eg short origin lines). In these cases the Contractor shall instead report on the marks that were looked for, the physical state of the proposed mark, and any other evidence (eg tie to other features, or recordings on recent plans).

5.5 *Site Photographs*

For each site visited photographs are to be taken of the mark and site. Site photo(s) should be taken that show the mark in relation to its surroundings, including features which may help to locate the mark. Usually this will require at least two photos of the site: one showing the immediate site and one showing a more extended view.

5.6 *Mark and Site Details*

For each site visited, sufficient mark and site details are to be recorded to enable a Report of Maintenance Work Completed and Required to be compiled.

Access Diagrams are not required.

6 Contract Deliverables

The format and content of the contract deliverables for Geodetic Control Survey are contained in the Specifications for Geodetic Contract Deliverables.

Appendix 1: Guidelines on Geodetic Good Survey Practice

The following field procedures are to be followed to ensure good survey practice:

- all field equipment shall be calibrated and checked prior to and on completion of the survey
- specific procedures shall be adopted to ensure that instrument centring and heighting errors do not go undetected
- where GNSS is used field procedures shall be adopted to minimise the effects of multipath and sufficient satellites shall be used to ensure a strong geometry
- all field measurements shall be independently checked and recorded
- two independent setups shall be undertaken on each mark
- sufficient time shall be allowed to ensure that GNSS satellite geometry changes to minimise the effects of multipath and other errors
- hanging lines shall be avoided where possible and where used sufficient checks shall be carried out to ensure no errors in the data
- sufficient observations shall be collected to ensure that a free and fixed network adjustment can be performed to check that the required survey accuracy standard has been met
- when doing mark reliability checks the Cadastral Survey Guidelines shall be followed.
- check to ensure the relative accuracy between new and existing nearby control is achieved

Appendix 2: Guidelines for Assessing Data Accuracy

1 Introduction

The guidelines in Section 2 of this Appendix relate to geodetic Orders 0-5 only. Minimally constrained network adjustments can be used to assess the strength of the network, detect outlying observations and determine whether the Class standards have been achieved. However, the Order standards will apply to fully constrained networks, ie, they apply to final coordinates.

Note that it is possible for a set of observations to meet a high Class standard but for the resulting coordinates to not meet the corresponding Order standards due to errors in the existing control or failure to adequately connect to sufficient higher Order marks. For example, a deformation survey may meet Class B10 standards but the connections to the existing network may only permit 3rd Order coordinates to be generated.

1.1 Absolute Coordinates

The application and testing of these standards depends on the method of network adjustment. There are 3 fundamental cases for fully constrained adjustments.

1. A weighted least squares or "Bayesian" least squares adjustment in which weights are assigned to the coordinates of higher order marks. For example, a 4th Order adjustment with no fixed marks where 3rd and higher Order mark coordinates are assigned weights according to their accuracies. These weights may be derived from earlier adjustment or may be based on the nominal accuracies prescribed by these standards; eg., 100 mm at the 95% confidence limit for 3rd Order horizontal coordinates. This results in a more correct adjustment than the classical method described below. However, coordinates of higher order marks are changed by the adjustment and this may be undesirable.

2. A "classical" adjustment where the coordinates of higher order marks are held fixed. For example, a 4th Order adjustment where the coordinates of 3rd and higher Order marks are held fixed. This ensures that these mark coordinates are not changed by the adjustment of the lower order network. This method incorrectly treats the coordinates of the fixed marks as if they had no error.

3. A hybrid adjustment where a number of different orders are adjusted together with the coordinates of the highest order marks being held fixed. For example, a combined 3rd and 4th Order adjustment where the coordinates of 2nd Order marks are held fixed.

For a weighted least squares adjustment, all marks shall have 95% confidence ellipses with semi major axes less than the maximum coordinate accuracy outlined in Table A2 of this standard. For example, all 4th Order marks shall have 95% confidence ellipses (horizontal) with semi major axes less than 112 mm. The 95% vertical uncertainties shall be less than 335 mm.

For a classical adjustment, the allowed size of error ellipses can be determined from Table A3 of this standard. The columns represent the Order of the fixed marks. The rows represent the Order of the marks being adjusted. For the classical adjustment, the 95% error ellipses (horizontal) of the 4th Order 2000 marks shall be less than 50 mm. The 95% vertical uncertainties shall be less than 150 mm.

For the hybrid adjustment examples given above, the 95% error ellipses (horizontal) of the 4th Order marks shall be less than 71 mm while those of the 3rd Order marks shall be less than 50 mm. The 95% vertical uncertainties of the 4th Order marks shall be less than 212 mm while those of the 3rd Order marks shall be less than 150 mm.

1.2 Relative Accuracy

Least squares adjustment allows the relative accuracy of adjusted marks to be derived from the inverse of the normal matrix. This can be calculated regardless of whether the line between the marks was directly observed or not. Many least squares programs, including Land Information New Zealand (LINZ's) SNAP, allow this information to be generated and output.

In order to confirm that the relative accuracy standards have been met, relative 95% error ellipses between all marks shall be generated and compared with the corresponding relative accuracy standard. Details of the relative accuracy standards for each Order, expressed in terms of Class standards, are shown in Table A2.

For lines between marks of different order, the relative accuracy standard of the lowest order shall apply. For example, a line between a 2nd and a 5th Order mark shall have a horizontal uncertainty given by the 5th order 2000 standard of M30 or 10 mm + 30 ppm at 95% confidence, not the 2nd Order standard of M1 or 3mm + 1ppm at 95% confidence.

◆ **Table A1. Standards for NZGD2000 Class Categories**

Class	95% Confidence Limit Accuracy Standard	
	Constant e (mm)	Line length error p[1] (ppm)
B10	3	0.01
B30	3	0.03
B100	3	0.1
B300	3	0.3
M1	3	1.0
M3	10	3.0
M10	10	10
M30	10	30
M100	10	100

1 Although p is a dimensionless quantity, when it is used in the 95% confidence limit formula in section 5.4 it has the effect of being a ppm accuracy standard.

◆ **Table A2. Standards for Order Categories**

Order	Control Network	95% Confidence Limit			
		Horizontal Coordinate Accuracy		Height Coordinate Accuracy	
		Class	Max Error mm	Class	Max Error mm
Orders for 2D and 3D Position					
0	Geodetic and Global network	B10	50	B30	150
1	Geodetic	B100	71	B300	212
2	Geodetic	M1	87	M3	260
3	Geodetic	M3	100	M10	300
4	Geodetic	M10	112	M30	335
5	Geodetic and cadastral	M30	123	M100	367

◆ **Table A3. Standard for Relative Accuracy Between Order Category Control Marks**

	Relative Horizontal Coordinate Accuracy (mm)						Relative Vertical Coordinate Accuracy (mm)					
Order	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0	-						-					
1	50	-					150	-				
2	71	50	-				212	150	-			
3	87	71	50	-			260	212	150	-		
4	100	87	71	50	-		300	260	212	150	-	
5	112	100	87	71	50	-	335	300	260	212	150	-

2 Guidelines to Check for Compliance with these Standards

The LINZ adjustment software package SNAP (Version 2.3.11 dated 18 May 2009 or greater) is to be used to check for compliance with the standards in the Tables above. A copy of SNAP and its associated utilities may be obtained from the LINZ web site at http://www.linz.govt.nz/software-downloads/snap/index.aspx.

Reasonable and justifiable *a priori* errors (observation accuracies) in terms of the methodology used should be assigned to the data. These should be no greater than the values in Table A4 according to the Order of coordinates to be defined from the survey.

Different error models may be used for different subsets of the data, however the use of these different error models should be justifiable.

Note: when using SNAP, any a priori errors of observations shall include any re-weighting that has been carried out of the dataset. This same re-weighting must be used in all the tests. The errors assigned to the observations must be one of the options specified in Table A4.

◆ **Table A4: Maximum *a priori* Error of Observations**

		Constant (e)				Line Length Error (p)		
Order		**E mm**	**N mm**	**U mm**		**E ppm**	**N ppm**	**U ppm**
0		1.2	1.2	1.5		0.004	0.004	0.015
1		1.2	1.2	1.5		0.04	0.04	0.15
2		1.2	1.2	5		0.4	0.4	1.5
3		4	4	5		1.2	1.2	5
4		4	4	5		4	4	15
5		4	4	5		12	12	50

2.1 Accuracy Tests

The survey data, both observations and assigned *a priori* errors, shall be tested by a series of adjustments as follows:

1. Observation Accuracy Test: this tests that the observations are as accurate or better than the assigned *a priori* errors.
2. Relative Coordinate Accuracy Test: this tests the relative accuracy of coordinates derived from the survey.
3. Absolute Coordinate Accuracy Test: this tests the accuracy of the derived coordinates in terms of the higher order marks controlling the survey.

Check 1 tests the implementation of the survey and checks 2 and 3 test the design of the survey.

2.2 Observation Accuracy Test

The accuracy of the observations shall be tested by a free-net adjustment. The observational accuracy requirements are achieved if the following conditions are met:

1. the standard error of unit weight is no more than 1; and

2. all *a priori* standardised residuals are less than a limit R_{max} which depends upon the degrees of freedom in the adjustment. R_{max} is calculated from the degrees of freedom n as

$$R_{max} = P^{-1}((1 + 0.95^{1/n})/2)$$

where P^{-1} is the inverse cumulative standard normal probability distribution function. This function is evaluated in Table A5.

◆ **Table A5: Allowance for Degrees of Freedom**

n	R_{max}
10	2.80
20	3.02
50	3.28
100	3.47
200	3.66
500	3.88
1000	4.05

Note: Values calculated from the degrees of freedom in the free-net adjustment. For degrees of freedom not listed, either calculate using the formula, or take the smaller of the nearest R_{max} values.

2.3 Relative Coordinate Accuracy Test

The relative accuracy of the derivable coordinates is tested in a free-net adjustment. The relative accuracy test uses the calculated *a priori* relative horizontal error ellipse and the *a priori* relative vertical error between every pair of marks.

The (1 standard error) horizontal error ellipses from the adjustment are multiplied by a factor f of 2.45 to obtain 95% confidence limits.

The (1 standard error) height errors from the adjustment are multiplied by a factor h of 1.96 to calculate 95% confidence limits.

The relative coordinate accuracy requirements are met if the relative horizontal and vertical 95% confidence limits between every pair of marks are less than the values defined in Table A6 for the order of the survey. In this table the relative accuracy comprises a distance independent component (in mm) and a distance dependent component (in ppm). These are to be combined using a root mean square formula. For example in a 4th order survey of two marks 2km apart the relative horizontal confidence limit has components of 10mm and 10ppm × 2km = 20mm, so the test value is $\sqrt{(10^2 + 20^2)} = 22\text{mm}$

Table A6: Test for the Accuracy of Coordinates

Order	Horizontal			Vertical		
	relative (mm)	relative (ppm)	absolute * (mm)	relative (mm)	relative (ppm)	absolute * (mm)
1	3	0.1	50	3	0.3	150
2	3	1	50	10	3	150
3	10	3	50	10	10	150
4	10	10	50	10	30	150
5	10	30	50	10	100	150

* relative to higher order control

2.4 Absolute Coordinate Accuracy Test

The "absolute" accuracy of the coordinates is defined by the *a priori* error ellipses in a constrained adjustment in which the coordinates of the control marks are held fixed.

The absolute accuracy requirements are met if the horizontal and vertical 95% confidence limits of all marks are less than the values specified in Table A6 for the order of the survey.

The (1 standard error) horizontal error ellipses from the adjustment are multiplied by a factor f of 2.45 to obtain 95% confidence limits.

The (1 standard error) height errors from the adjustment are multiplied by a factor h of 1.96 to calculate 95% confidence limits.