Establishing and Replacing Order 5 Control Marks

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Overview

• Purpose of the Workshop
• Network Design – Where could a new geodetic mark go?
• Field Work – What to consider when in the field?
• Mark Attribute – What makes a good geodetic mark?
• Deliverables – What to submit to LINZ?
• GNSS – What to consider during processing?
The Geodetic Point of View!

- New Zealand Vertical Datum 2009 (NZVD2009)
  - 8 cm nominal accuracy
- Vertical Datum Improvement Project
  - 3cm accuracy (in developed areas)
  - Complete in 2016
- Geodetic control marks Order 0-5 have ellipsoid heights which makes it possible to calculate NZVD2009 heights
The Geodetic Point of View!

The National Geodetic Office get reports of geodetic marks getting **renewed/reinstated**

Is this a problem?

**Order 5 geodetic marks**

<table>
<thead>
<tr>
<th>Order</th>
<th>NZGD 2000 COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latitude:</td>
</tr>
<tr>
<td></td>
<td>37° 39' 36.34468'' S</td>
</tr>
</tbody>
</table>

Order: 5  
Authorised: 25-Oct-2011  
Reference: 2010103 Waikato (Part 4)
Definitions

Reinstated or Renewed Mark

• Mark installed in the EXACT SAME HORIZONTAL AND VERTICAL POSITION.

• The 3D coordinates do not change between the original and the reinstated marks.

Replacement Mark

Re-establish Control

• Replacement mark NOT IN THE SAME POSITION as the original mark.

• Should be installed in a more appropriate or better protected location

• Connection to the cadastre is important

& NOT RECOMMENDED for Order 5 or better
Give your GNSS data extra life

- How many times have you set a GNSS base receiver up on a cadastral survey in a remote area away from existing NZGD2000 Control?
- As the data is collected are you thinking, great, no connection to NZGD2000 control required, or
- Are you thinking, if only my data could be submitted to LINZ to establish control in this area?
- With a slight alteration to field procedures and sending the resultant data to LINZ in a specified format the second option is achievable!
Other useful Data

- Control for photogrammetry or LiDAR surveys
- Control for an engineering project
- Base station data for an RTK survey
- Replacement of mark(s) in an area already covered by a network
- Each of these may have its own requirements but could all be of use to upgrade the control system
Influences of the network purpose

- Greenfield networks may be staged – initially with marks outside the design area - connection to cadastre in this area then uniform coverage when roading complete
- Networks for LiDAR often have requirements such as the aircraft having to operate within certain distances of ground base stations
- Engineering surveys may require accuracies greater than that provided by existing NZGD2000 networks in a localised area
- Spacing of marks may vary from Order 5 requirements
Spacing of Marks for Order 5

- Requirements for Order 5 networks is influenced by the SG,s Rules for connection of CSD’s to NZGD2000
- Urban density is based on 200m radius around each control mark – allowing for overlap -approximately 300m between marks
- Rural density is based on 2000m radius around each control mark – allowing for overlap -approximately 3000m between marks
Variation to Mark Density

- Density may be varied to suit areas of more intense rural development around towns and cities.
- As existing connection into the cadastre is important for Order 5, some flexibility exists for non-cadastral data.
- Marks can be upgraded to Order 6 in the same network as Order 5.
- A pair of marks is sometimes useful if terrestrial surveys are attached to control.
Use of existing marks

- Whenever a mark from an existing CSD or plan is upgraded to Order 5 evidence of reliability is required
- Marks must be proven reliable by survey as for a CSD
- Evidence can be provided as:
  - Field note with diagram
  - Traverse Sheet
  - A file as specified by NGO
Tools to Aid with Design

- Background mapping using GIS software or KML files in Google Earth
- Buffers around design marks on screen to indicate coverage
- Locations of higher order NZGD2000 control
- Locations of all existing marks in the geodetic database, some of which may be suitable for upgrade
- Underlying existing cadastre and marks from Landonline
Restrictions to Design

• Initial use of Google Earth to check sky visibility
• Avoid locations such as busy roads especially State Highways
• Stable locations – unlikely to be disturbed
• RTK restricted by radio or cell coverage and lesser accuracy of method meaning shorter lines than for static GNSS
• Lack of higher Order control to connect to/ suggest placing of an Order 4 mark to NGO
Network Design Mapping

- Useful for -
  - Coverage
  - Identification of obstacles
  - Higher order control locations
  - Design of observation sessions
  - Planning routes to marks
Connection to Higher Order Control

- All Order 5 surveys must be connected to a minimum of two higher Order marks
- Within 3km of network being surveyed in urban areas
- Plus connections to a CORS station if closer than 20km
- Where longer lines are measured occupation times can be extended
- In remote locations only connections to CORS stations may be required
- CORS stations record at 30 seconds
Reducing Error

- Optical plummets and bubbles in exact adjustment during survey
- Use tripods that are in good condition (including pole tripods)
- Incorrect antennae heights are a source of error
- Measure heights in two different measurement units (check)
- Measure from high point of mark to ARP
- Ensure RTK Poles do not slide into survey marks (coin)
- Check plumbing and height again after measurement complete
- Avoid multipath situations (your vehicle could be one)
Field Procedure

- OSH – make sure you are safe from hazards
- Ensure you have TTM relevant to location – Local Authority permission
- Ideally mark names should be in terms of a CSD,
- If not on a CSD use a unique identifier for each mark
- Pre-allocate codes from NGO and use in field
- Two independent sessions per mark (change height)
- Record field notes of all relevant data (Example on LINZ website)
- Minimum 20mins between starts of sessions
Heights

- Normal-orthometric height system (GRS80)
- NZGeoid2009 reference surface
- Offsets to local datum's
- Transformations between local and geodetic datum
Heights in terms of?

- Order 5 requires ellipsoidal heights
- Orthometric heights by geoid model to NZVD2009
- Tie to local orthometric heights on periphery of network to ensure heights of new stations are in terms of a local datum
- Any surveys without independent occupation of marks will be Order 6, no matter how long the occupations. i.e No Heights
- Use SNAP or conversion on LINZ website to obtain NZVD2009 heights
Ease of Use

• In terms of ease of location, ability to safely occupy, and easily be identified as a survey mark.
• Marks in the road which require traffic management lack efficiency.
• Marks located on Public land are more desirable than on Private land.
Longevity/Stability

- Plastic/cast iron protection boxes are ideal.
  - Shows obviously where the mark is
  - Protects the mark when not being used
  - Mark is never above ground level (e.g. not a tripping hazard, unlikely to be damaged by mowers, etc)

- Buried marks.
  - Must be easy to locate (metal detector, with minimal digging)
  - Plastic marker posts are encouraged for marks in rural areas

- Be aware of what is underground when selecting sites for new control marks.
- Remain useable for approximately 50 years.
Inter-visibility vs. Permanence

- Good to have inter-visible marks where possible, particularly in areas with poor GNSS suitability
- Avoid the sacrifice of permanence to achieve inter-visibility
- Location is paramount – other ways to traverse in
- Installing two inter-visible marks is desirable
- Inter-visibility was paramount, still important?
- Do the majority of Surveyors own GNSS?
Mark Location Attributes

- When selecting a location for a new mark, consider the following:
  - Sky obstruction, require 70% sky visibility above 15 degrees
  - Sources of multipath, ideally be 20m clear of potential multipath sources
  - Sources of radio interference, ideally 50m clear of sources of radio interference
  - Think ahead, is there likely to be tree growth which may disturb the mark in the ground or obscure sky visibility in the foreseeable future?
  - SG rules expect a mark to remain useable for at least 50 years
The Good...

- Ease of use.
- 70% sky visibility above 15 degrees.
- Clear of sources of multipath.
- Clear of sources of radio interference.
- Future growth would be manageable.
The Bad...

- Clear of sources of multipath.
- Clear of sources of radio interference.
  70% sky visibility above 15 degrees from the horizon.
  Very Poor available satellite geometry.
And the Ugly...
Modifications to Geodetic Marks

• Horizontal
  – If, when maintaining a geodetic mark, the horizontal position alters by more than 3mm the mark is deemed new and a new name and code shall be provided. The difference should be measured and the old mark deemed destroyed.

• Vertical
  – 3mm movement in the height will affect all high order marks (0-4) and order 1V or 2V and will require a new node to be created. In the case of an order 5 mark, a 10mm alteration in the height will constitute a new 3D position.
Mark Improvement

- Mark heights and positions generally tend to be altered when improving an existing mark.
- Altering the mark height is usually carried out to mitigate a health and safety risk, or to protect a mark at risk.
- Large diameter marks without a common reference point are poor geodetic marks.
  - Typical example, a tube grouted with a pin.
Replace an Existing Mark

- Does not require the mark be in the same position
- Generally, we replace an existing mark if it is in danger of being damaged or destroyed.
- Preferable for replacement mark to be put at a nearby site which is likely to remain useable for 50 years
- At least two ties are required to prove reliability of an existing mark to be upgraded
- When placing a new mark, required to connect into the cadastre through a minimum of two reliable old marks.
Available Survey Materials

- 12/22mm SS Pins
- Aluminium ID Plates
- Aluminium Trig Station Advisory Plates
- Bronze ID Plaques
- Bronze Mushroom Plaques
- Cast Iron Frames/Lids
- Plastic PRM Protection Boxes
- White Plastic Marker Posts
- Clark Beacons
- White Sight Board Panels
- White Target Board Vane Braces
- White Cross Braces
- Black Target Board Vanes
- Alloy Head
- Pipe Mast
- Pipe Legs
- Waratah Anchors
- U Bolts (Clamps)
- Mast Pins
- 50/200mm Assembled Bolt
<table>
<thead>
<tr>
<th>From Mark</th>
<th>To Mark</th>
<th>Date</th>
<th>Time (NZST)</th>
<th>Delta X</th>
<th>Delta Y</th>
<th>Delta Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXX</td>
<td>YYYY</td>
<td>2011.07.18</td>
<td>15:35</td>
<td>100.059</td>
<td>200.752</td>
<td>300.989</td>
</tr>
<tr>
<td>YYYY</td>
<td>IT IV</td>
<td>2011.07.18</td>
<td>14:30</td>
<td>50.159</td>
<td>75.489</td>
<td>100.123</td>
</tr>
<tr>
<td>YYYY</td>
<td>DP 412345</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The XYZ vector between two marks is the difference in the XYZ values for each mark.

Image from Where in the World are We?: A technical guide to datums and projections in New Zealand
PositioNZ stations

PositioNZ RINEX data

Bottom of Notch (BoN)
Antenna Reference Point (APR)
Vertical Reference Point (VRP)
Two Types of PositioNZ Monuments

Two different monuments = two different heights
Antenna Phase Centre Model

- APCV
- APC (mean)
- Antenna Offset
- ARP
- Antenna Height
- Survey Mark
Antenna Phase Centre Issues

- PositioNZ stations are Trimble Zephyr Geodetic 2
- Your software might not be Trimble
- Antenna type code in the RINEX header information
- Unrecognised in your software

Solution

- Upgrade your software
- Contact your software provider
RINEX Format

Receiver **IN**dependent **EX**change (RINEX) data

**Questions:**

What is the height recorded in this RINEX file and what is it referring too?

What is the logging rate of a PositioNZ station?

How many satellites were measured in the first observation set?

How does the RINEX file know the antenna type?

For more information on RINEX format refer to [ftp://ftp.unibe.ch/aiub/rinex/rinex211.txt](ftp://ftp.unibe.ch/aiub/rinex/rinex211.txt)
## The RINEX file...the data within

<table>
<thead>
<tr>
<th>Time</th>
<th>Observation Data</th>
<th>M (Fixed)</th>
<th>RINEX Version / Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013Mar15</td>
<td>03:11:40UTCFOX</td>
<td>30106516</td>
<td>03:11:40UTCFOX / RUN BY / DATE</td>
</tr>
</tbody>
</table>

**CODE**
- **50214**
- **GEO**
- **GeoNet**
- **5945701.53**
- **1411031118**
- **-9580565.5415**

**GNSS**
- **TRIPLEX METER**
- **4.17**

**TWO**
- **TXM559710.00**
- **ANT # / TYPE**
- **NOXX**
- **APPROX POSITION XYZ**
- **0.0000**
- **0.0000**
- **0.0000**

**L1**
- **C1**
- **L1**
- **S1**
- **P1**
- **C2**
- **L2**
- **S2**
- **P2**

**TIME**
- **20.0000**
- **16**
- **2013**
- **8 15 0 0 0 0 0.000000 0.000000 0.000000 GES**

**END OF HEADER**

| 23078510.803 | 12176431.288 | 7 45.700 |
| 94502652.094 | 29.700 | 23078513.309 |
| 8529150.948 | 117580312.867 | 7 43.900 |
| 5191332.416 | 7 42.900 | 21971064.027 |
| 23600988.561 | 12030555.188 | 7 42.400 |
| 56638483.8794 | 28.700 | 23360068.434 |
| 20231395.001 | 10631790.107 | 7 49.000 |
| 62834786.0554 | 58.900 | 20251536.958 |
| 22128586.685 | 11265224.799 | 7 47.100 |
| 50596475.0359 | 33.400 | 22242387.777 |
| 21941119.703 | 11455667.832 | 7 43.400 |
| 58503564.862 | 41.900 | 21441525.488 |
| 23521586.350 | 115162751.948 | 7 42.900 |
| 92682024.959 | 32.700 | 22452809.605 |
| 22024027.117 | 112011063.556 | 7 45.600 |
| 90184770.8254 | 29.300 | 22024029.375 |
| 21948896.297 | 114945773.911 | 7 45.300 |
| 9023214.075 | 32.900 | 21448975.551 |
| 23552656.516 | 12136585.649 | 7 45.300 |
| 9452149.195 | 41.300 | 23365023.264 |

### Additional Information
- **All RINEX heights are to ARP**
- **17 satellites**
  - **10 GPS (G) satellites**
  - **7 GLONASS (R) satellites**
- **Logging rate = 30 seconds**
- **Zephyr Geodetic 2 antenna code**

Refer to... [https://www.ngs.noaa.gov/ANTCAL/](https://www.ngs.noaa.gov/ANTCAL/)
## Mark Data Format

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Ellipsoid hgt (m)</th>
<th>Vertical Reference Point</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXX</td>
<td>SS I SO ZZZZZZ</td>
<td>-41.8056208</td>
<td>171.256780</td>
<td>100.01</td>
<td>Dimple in centre of S/S pin</td>
<td>Stainless steel pin in concrete block, down 0.3 in berm outside 25 Smith Street.</td>
</tr>
<tr>
<td>YYYY</td>
<td>IS 2 SO ZZZZZZ</td>
<td>-41.8056104</td>
<td>171.256787</td>
<td>200.02</td>
<td>Dimple in centre of spike</td>
<td>Flush with curb outside 52 Brown Street.</td>
</tr>
<tr>
<td>IT IV DP 412345</td>
<td>-41.8056202</td>
<td>171.256730</td>
<td>200.03</td>
<td></td>
<td>Centre of 10 cent piece over existing tube</td>
<td>Down 0.5 in berm, Rapid 111 Farm Road.</td>
</tr>
</tbody>
</table>
Photos – what to avoid
Access/Finder Diagram

Access Diagram: May not be to scale
Reliability Check

The reliability of any existing mark to be upgraded to Order 5 must be proven and documented evidence provided.

- If you are submitting a CSD, you can either prove reliability on plan face, or on field note / traverse sheet as a supporting document.

- If there is no CSD, provide field note / traverse sheet with geodetic survey, signed off by a cadastral surveyor.
Survey Report

• What is the purpose of the survey, what is it going to achieve

• Methodology – length of session, RTK, static or mixture, how many independent mark occupations
Geodetic Resources

Initiatives

- Submit your own data to the Geodetic System 2010
- Geodetic Control Pilot 2012

Relevant documents...

- Guidelines for Simplified Geodetic Control Survey v1.0
- SNAP Guidelines for GNSS Geodetic Control v 1.0
- Standard for tiers, classes, and orders of LINZ data
- Specification for Geodetic Services v1.1

## Geodetic Feedback Form

### MARK IDENTIFICATION

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGGC</td>
<td>LT EX-401827</td>
<td></td>
</tr>
</tbody>
</table>

### MARK INFORMATION UPDATE

- **Proposed name**: LT EX-401827
- **Mark type**: Take
- **Beacon type**: Built
- **Protection type**: No protection
- **Mark status**: Partially Faded/Flaked

### MARK MAINTENANCE RECOMMENDATIONS

- **Stabilise mark**
- **Replace mark**
- **Insert stainless crawl pin**
- **Repair mark e.g. IT rusted**
- **Clear vegetation**
- **Repair structure**

### CANTERBURY EARTHQUAKES

- **Unproven**: UNPROVEN
- **Reference Survey**: 

### GENERAL COMMENTS

Any information you enter below will be submitted to LINZ for processing. This information will not be displayed to other users.

### OTHER MAINTENANCE SUGGESTIONS AND FURTHER DETAILS:

You can upload a photograph of the site or mark to illustrate your comments. Note that by uploading images to LINZ, you are transferring copyright of those images to LINZ. The images may be modified, displayed on the LINZ website, and used in any way by LINZ without acknowledgement of their source. Please try to avoid including recognisable people in photographs - for privacy reasons these will be edited before being used, or will be rejected.

I acknowledge that copyright of uploaded images is transferred to LINZ.

- **Site photograph**: Choose File
- **Mark photograph**: Choose File

### Information for EGGC

- **Mark details**
- **Show on map**
- **Save mark for download**
- **User feedback/unproven status**
- **Maintenance history**
  - Mark diagram dated 12-Apr-2012
  - Mark diagram dated 9-Nov-2010
  - Site photograph (2012)
  - Site photograph (2010)
  - Site photograph (2010)
  - Reliability diagram (2010)
Geodetic Marks – Mobile App

LINZ Geodetic database on the go:
• Locate nearby geodetic marks
• Navigate to a selected mark
• View mark data
  - Coordinates
  - Mark details
• Save selected marks

http://www.linz.govt.nz/geodetic
Contact the National Geodetic Office

Email the geodetic team directly

CRM_geodetic@linz.govt.nz