

**Median water table elevation in  
Christchurch and surrounding area  
after the 4 September 2010 Darfield Earthquake  
Version 2**

S. van Ballegooy, S. C. Cox, C. Thurlow,  
H. K. Rutter, T. Reynolds, G. Harrington,  
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**GNS Science Report 2014/18**

**May 2014**

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*The following report is an update of the median water table elevation report for Christchurch and surrounding areas released in March 2013 (GNS Report 2013/01). The revision encompasses an extension of the period of groundwater monitoring (4 September 2010 to 30 November 2013) and new surfaces for improved definition of water table fluctuation.*

## **BIBLIOGRAPHIC REFERENCE**

S. van Ballegooy, S. C. Cox, C. Thurlow, H. K. Rutter, T. Reynolds, G. Harrington, J. Fraser, T. Smith, 2014. Median water table elevation in Christchurch and surrounding area after the 4 September 2010 Darfield Earthquake: Version 2. GNS Science Report 2014/18, 79 pages plus 8 appendices.

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## **APPENDIX C: LIDAR INFORMATION**

### **LiDAR survey and benchmark comparisons**

**Figure C.1 Cumulative ground elevation difference**

**Figure C.2 Survey benchmark locations and residential land zonation categories**

**Figure C.3 Cumulative frequency plots of difference between the measured LiDAR elevations and the benchmark elevations from field surveys**

# LiDAR and survey benchmark comparisons

## 1 LiDAR survey data

The elevation of the ground surface around Canterbury was measured remotely using airborne LiDAR surveys. A baseline survey of Christchurch was flown in 2003 and additional surveys were flown after each of the main aftershocks. Results are reported in CERA (2014).

Airborne LiDAR provides measurements in GPS-space, with absolute elevations at X, Y northing and easting coordinates measured relative to the ellipsoidal datum of the satellite network. The measurement data, commonly termed a 'point cloud', was processed using the simultaneously recorded aerial photographs to identify and remove points reflected from water and from above-ground features such as structures and vegetation that were judged to be higher than 0.13 m above the surrounding ground surface.

The LiDAR was typically acquired at least one month after each major earthquake (with the exception of the post-September 2010 LiDAR that was flown the day after the 4 September 2010 earthquake). This delay provided time for ejected sand and silt to be removed from most locations in order to measure changes to the ground surface level. The extent of each LiDAR survey was different for each event, with the extent chosen to cover areas believed to have been affected by ground surface subsidence caused by the preceding earthquake.

The LiDAR surveys were acquired by AAM Brisbane (AAM) and New Zealand Aerial Mapping (NZAM). The suppliers also classified the acquired points as ground or non-ground. The LiDAR sources and commissioning agencies are listed in Table C1 below.

**Table C1- LiDAR source and commissioning agencies**

| DEM            | Source LiDAR                                           | Commissioning Agencies                                |
|----------------|--------------------------------------------------------|-------------------------------------------------------|
| Pre-earthquake | AAM, 6-9 Jul 2003                                      | Christchurch City Council                             |
|                | AAM, 21-24 Jul 2005                                    | Environment Canterbury & Waimakariri District Council |
|                | AAM, 6-11 Feb 2008                                     | Environment Canterbury & Selwyn District Council      |
| Post-Sept 2010 | NZAM, 5 Sep 2010                                       | Ministry of Civil Defence and Emergency Management    |
| Post-Feb 2011  | NZAM, 8-10 Mar 2011                                    | Ministry of Civil Defence and Emergency Management    |
|                | AAM, 20-30 May 2011                                    | Christchurch City Council                             |
| Post-June 2011 | NZAM, 18 & 20 Jul, 11 Aug, 25-27 Aug, and 2-3 Sep 2011 | Earthquake Commission                                 |
| Post-Dec 2011  | NZAM 17-18 Feb, 2012                                   | Earthquake Commission                                 |

## 2 LiDAR elevation accuracy and precision

The equipment and flying heights for the post-earthquake LiDAR surveys produced point clouds with a fundamental vertical specification accuracy of  $\pm 0.07\text{m}$ . This error excludes GPS network error and the approximations within the New Zealand Quasignoid 2009 (NZGeogrid2009) reference surface (with and expected vertical accuracy of  $\pm 0.06\text{m}$ ). The

equipment produces less accurate horizontal positions ( $\pm 0.4$  to  $\pm 0.55$  m), so elevations will be more accurate than 0.07 m for points directly beneath the aircraft and less accurate than this at the edges of the scan swath ( $\pm 20$  degrees from vertical). The pre-earthquake LiDAR point cloud had less accuracy and a larger spacing between the points.

The LiDAR survey suppliers offset the vertical elevation of the entire point cloud to accommodate atmospheric effects that affected the light path and hence the distance measurement, by comparing elevations with reference elevations from GPS field surveys of flat hard surfaces. The vertical precision is therefore the precision of the field survey, which for GPS surveys is typically quoted as 0.03 m (one standard deviation).

After each major aftershock, Land Information New Zealand (LINZ) re-surveyed the elevations and locations of a network of survey benchmarks around Canterbury. The LINZ surveys re-established the benchmark locations relative to the rest of the physical survey network around New Zealand. This survey information provides a convenient method of verifying the accuracy of the elevations provided by the GPS based LiDAR points against the ground based survey points. These also provide a larger, well distributed set of known elevations than those used by the LiDAR supplier, so they can be used as more-precise point cloud offsets.

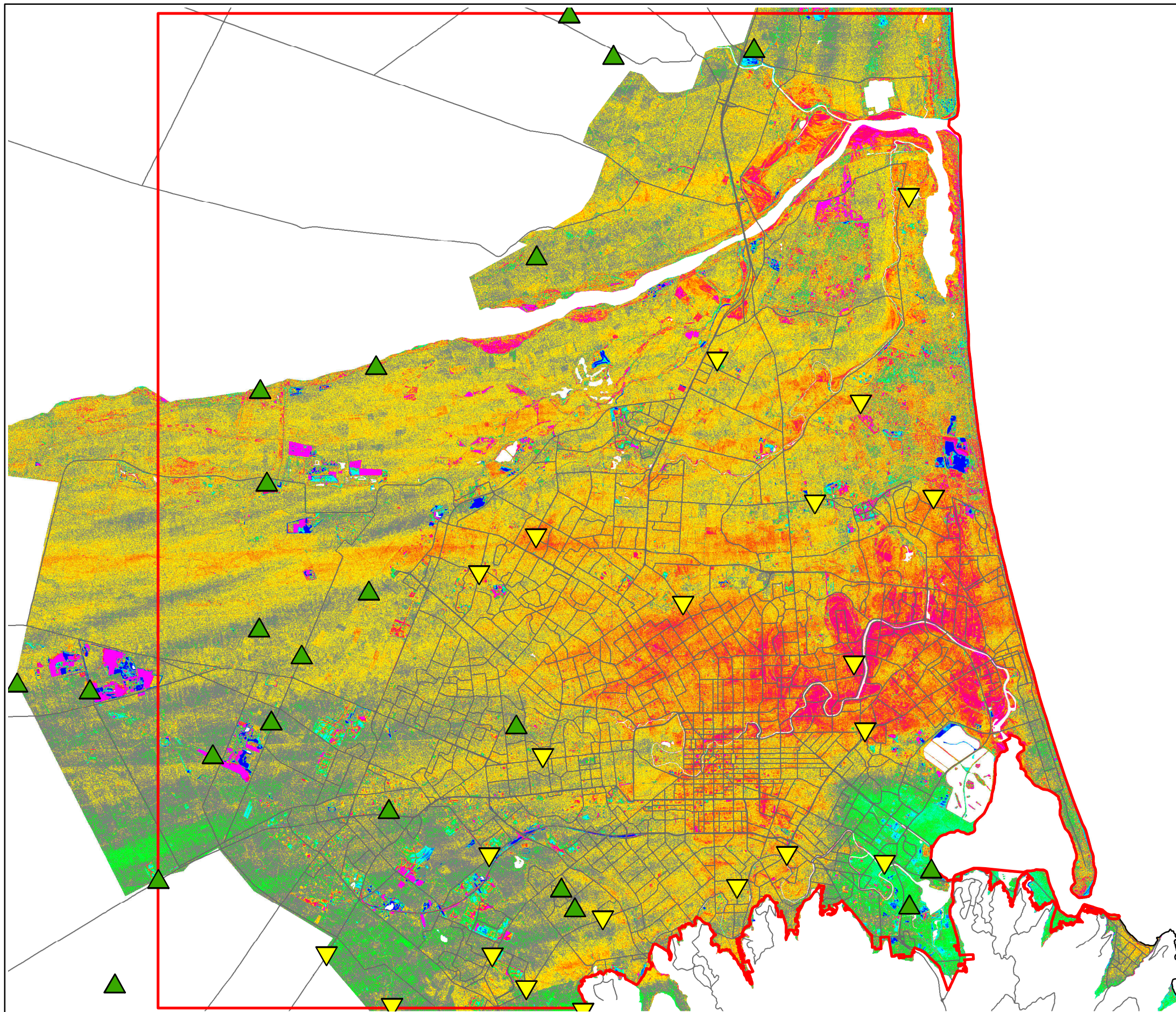
The complete set of benchmark locations are shown in Figure C.2. Only subsets of these benchmarks were surveyed before the 4 September 2010 earthquake and surveyed again after each particular earthquake (note that some benchmarks were not surveyed after some events and some were destroyed by localised movements).

The accuracy of the LiDAR point cloud elevations was evaluated by comparing selected LiDAR point elevations to the observed benchmark elevations. The ground returns within the point cloud are often relatively sparse so an algorithm was developed to provide the best estimate of the average elevation of the LiDAR returns surrounding each benchmark. The most expedient method of calculating the representative average was to:

1. Fit a plane to three or more LiDAR return elevations that are within a 0.75 m radius of the benchmark location. Using a plane rather than a simple average avoids bias when the returns were not uniformly distributed spatially around the benchmark;
2. Calculate the standard deviation of the errors comprising the differences between the LiDAR return elevations and the plane elevation;
3. Repeat steps 1. and 2. for radii of 1.5, 3.0 and 6.0 m; and
4. Calculate the elevation at the benchmark location using the plane that has the minimum standard deviation of errors.

The elevation difference between each measurement point and the benchmark were plotted over an aerial photograph, and points that were clearly not ground surface measurements (e.g. fence tops, vegetation, cars etc.) were removed from the data set. The resulting elevation differences have unquantified errors associated with the elevation difference between the benchmark and its surrounding ground. This includes differences associated with local features such as sloping ground (due to the lower horizontal position accuracy) and with kerbs and other depressed or raised surfaces.

A cumulative-frequency plot of the elevation differences is shown for each of the point-cloud sets in Figure C.3. This clearly illustrates the larger standard deviation for the older equipment used for the 2003 pre-earthquake LiDAR. It also shows that the elevations for the post-June 2011 LiDAR point cloud are about 50 mm too high relative to the other LiDAR point clouds, which are within the 30 mm tolerance for the GPS reference field surveys. On this basis, the post-June 2011 DEM has been adjusted downward by 50 mm.



**Legend**

**Monitoring Well Locations**

▼ CCC      ▲ ECAN

**Elevation Change (m)**

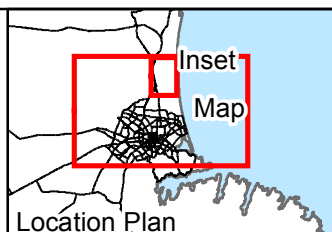
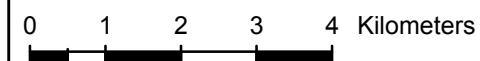
|                |                |
|----------------|----------------|
| ▼ < -1.0       | ▲ +0.1 to +0.2 |
| ▼ -1.0 to -0.5 | ▲ +0.2 to +0.3 |
| ▼ -0.5 to -0.4 | ▲ +0.3 to +0.4 |
| ▼ -0.4 to -0.3 | ▲ +0.4 to +0.5 |
| ▼ -0.3 to -0.2 | ▲ +0.5 to +1.0 |
| ▼ -0.2 to -0.1 | ▲ +1.0 to +1.5 |
| ▼ -0.1 to +0.1 | ▲ > +1.5       |

**Other**

□ Study Area

Notes: Road Database supplied by Terralink International Ltd.  
Contains data sourced from Land Information New Zealand  
under CC-BY. <http://creativecommons.org/licenses/by/3.0/nz/>

A3 SCALE 1:100,000

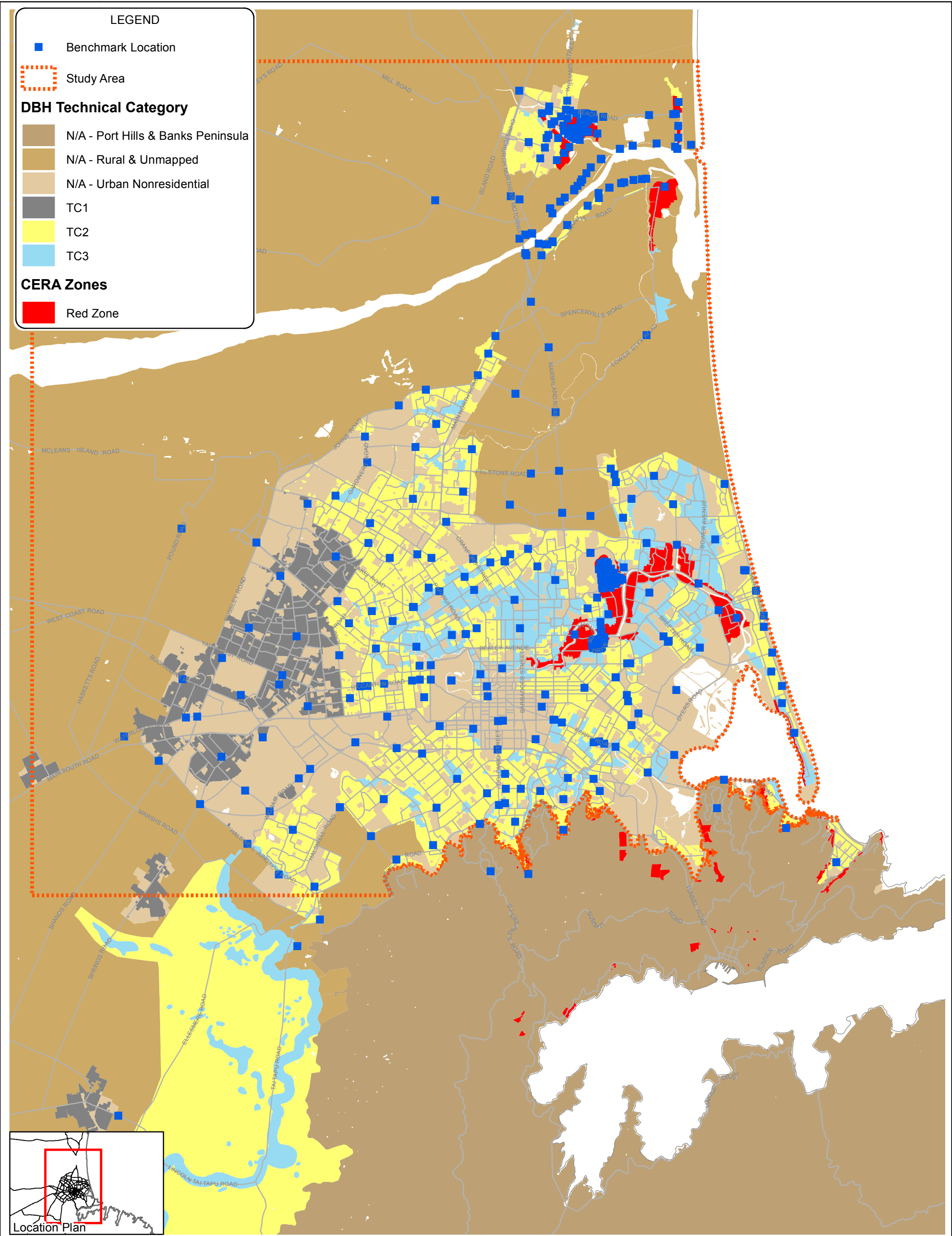


|                                                     |     |        |
|-----------------------------------------------------|-----|--------|
| DRAWN                                               | CXP | Feb.14 |
| CHECKED                                             |     |        |
| APPROVED                                            |     |        |
| ARCFILE<br>52020-0200-GWM55                         |     |        |
| SCALE (AT A3 SIZE)<br>1:100,000                     |     |        |
| Prepared By Tonkin & Taylor Ltd.<br>Ref. 52020-0200 |     |        |

# CHRISTCHURCH MEDIAN WATER TABLE ELEVATION REPORT Cumulative LiDAR Elevation Difference (Pre September 2010 to Post June/Dec 2011)

FIGURE No. Figure C.1

Rev. 0



Notes: Road Database supplied by Terralink International Ltd. Rivers, lagoons and coastline licensed under Creative Commons Attribution 3.0 New Zealand and sourced from LINZ. Crown Copyright Reserved  
A3 SCALE 1:100,000  
0 1 2 3 4 5 (km)



|                                 |     |        |
|---------------------------------|-----|--------|
| DRAWN                           | CXP | Apr.14 |
| CHECKED                         |     |        |
| APPROVED                        |     |        |
| ARCFILE                         |     |        |
| 52020-0200-SBM019               |     |        |
| SCALE (AT A3 SIZE)              |     |        |
| Prepared by Tonkin & Taylor Ltd |     |        |
| Ref. 52020-0200                 |     |        |

# CHRISTCHURCH MEDIAN WATER TABLE ELEVATION REPORT

Survey Benchmark Locations of those used in the Benchmarks and LiDAR comparison

FIGURE No. Figure C.2

Rev. 0

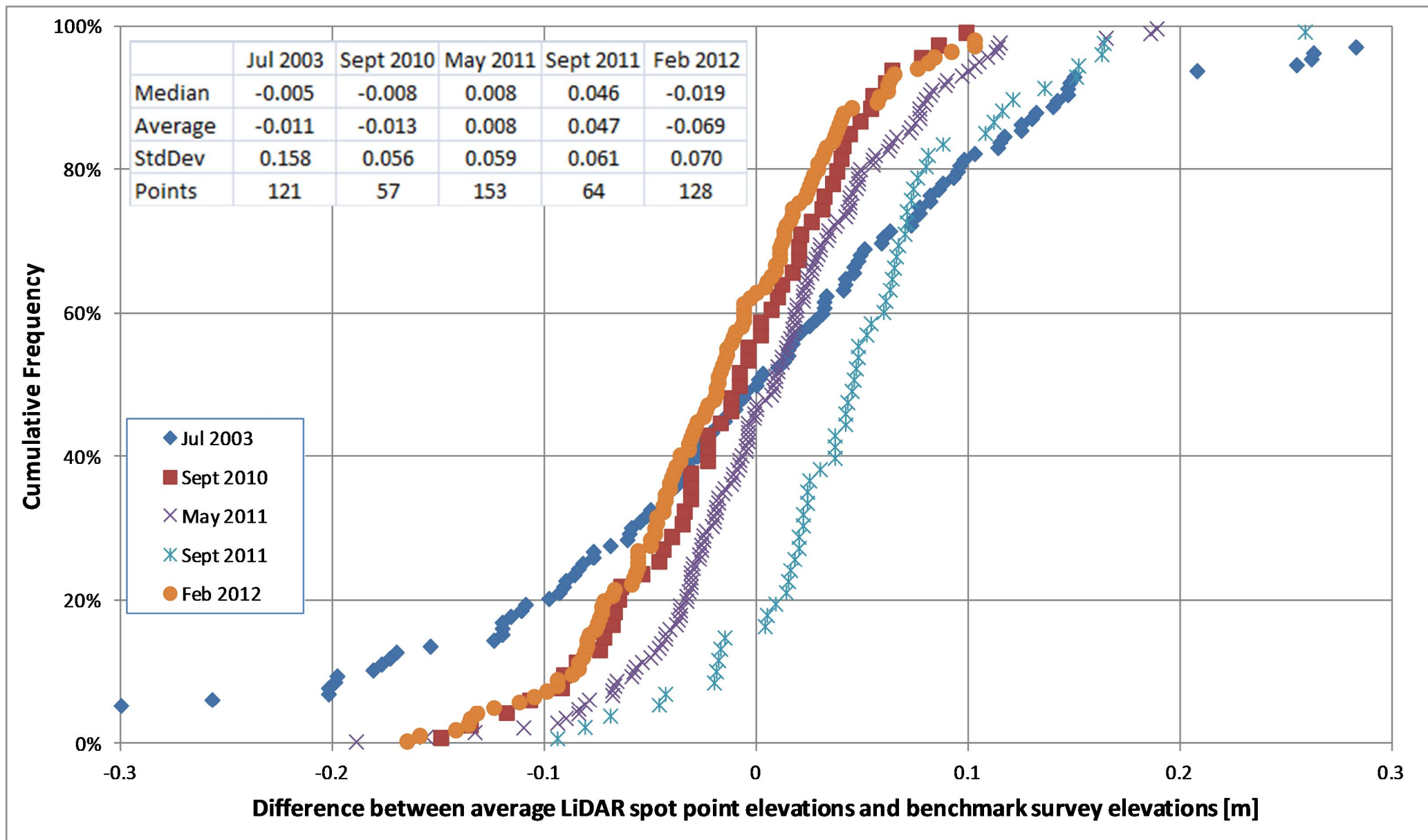


Figure C.3 – Cumulative frequency plats of the difference between the measured LiDAR elevations and the benchmark elevations from field surveys



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