Official – Sensitive

Volume change calculations for Land to the North of Bournewood Sand and Gravel Limited, Swanley By-Pass, Kent from March 2015 to December 2018

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1 Introduction

Environment Agency Geomatics were approached by Environment Agency Kent, South London and East Sussex to acquire aerial Light Detection and Ranging (LIDAR) elevation data over a site near Swanley By-Pass, Kent. The aerial data were acquired on 22 December 2018. Geomatics were also asked to estimate volume change within the site. This was carried out using archived LIDAR from 3 - 5 March 2015 and from 30 January 2018 acquired by Environment Agency Geomatics and the December 2018 LIDAR.

The work described in this report uses aerial LIDAR to calculate material volumes. Aerial LIDAR instruments use laser pulses to measure the distance between an aircraft and the ground surface. As the aircraft flies over the survey area a series of laser pulses are fired at the ground. In conjunction with very high accuracy navigation data, the laser pulses are used to build up an accurate elevation dataset of the ground below the aircraft, with spacings between the elevation measurements, or the resolution, of between 0.25 m and 2 m. Though the individual points of the LIDAR survey are slightly less accurate than a ground-based GPS survey, LIDAR instruments provide much more detail, collecting one million elevation measurements every 2 to 30 seconds. The specification for the current Environment Agency LIDAR system is that at least 66% of points are within 0.1 m of the actual value.

This high accuracy and fine detail make LIDAR surveys more accurate than ground-based GPS surveys for measuring volume on sites like the one covered in this report.

2 Method

The datasets used in this report are described in Table 1 and are shown in Figure 1 to Figure 5.

Table 1 Data used for Land to the North of Bournewood Sand and Gravel Limited site

Data type	Resolution (m)	Date acquired
LIDAR	1	3 - 5 March 2015
APGB aerial photography	0.25	9 August 2015
LIDAR	1	30 January 2018
APGB aerial photography	0.25	21 October 2018
LIDAR	0.5	22 December 2018

APGB= Aerial Photography Great Britain

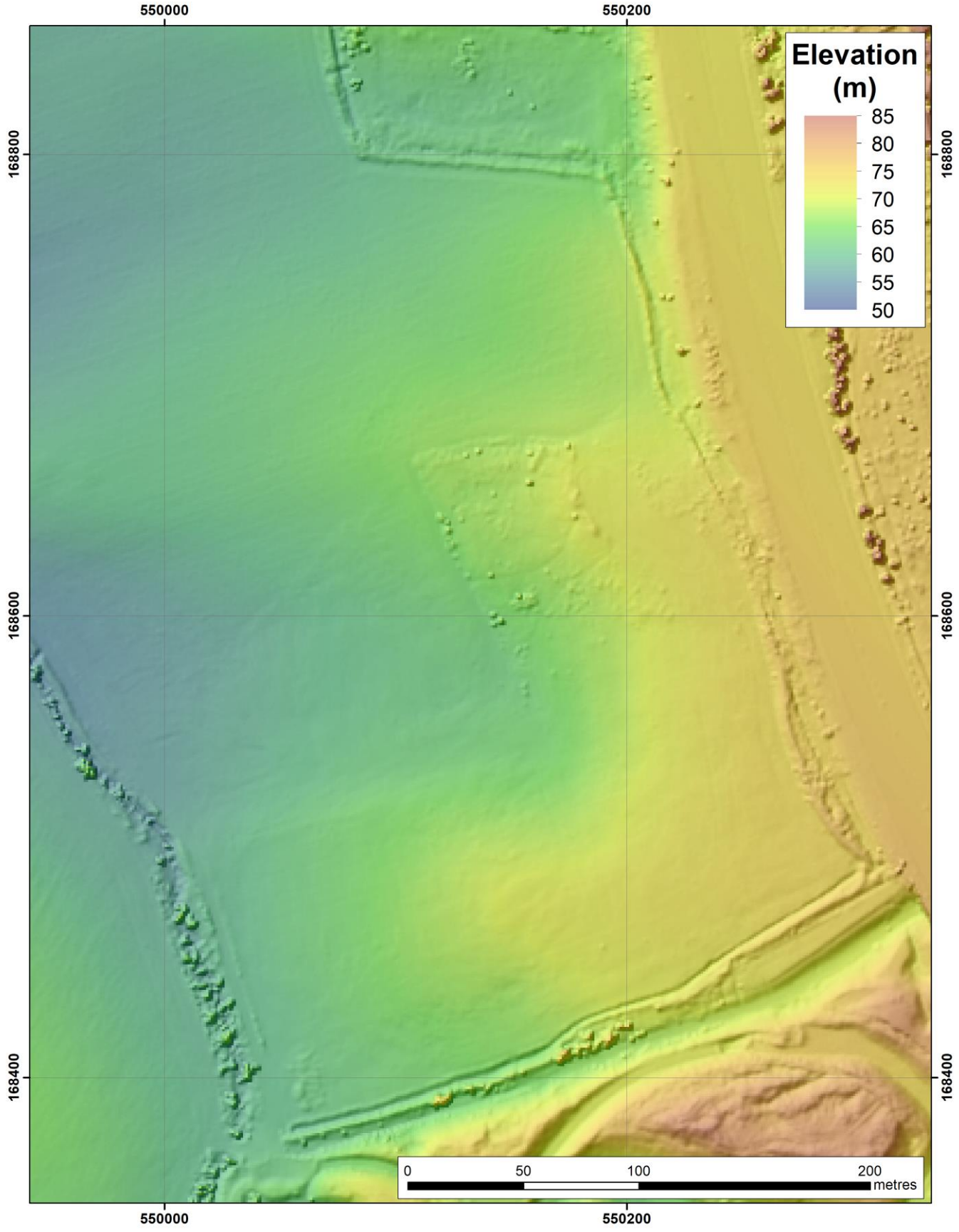

Figure 1 LIDAR elevation data acquired on 3 - 5 March 2015 for the Land to the North of Bournewood Sand and Gravel Limited site.

Figure 2 APGB aerial photography acquired on 9 August 2015 for the Land to the North of Bournewood Sand and Gravel Limited site. © Bluesky International.

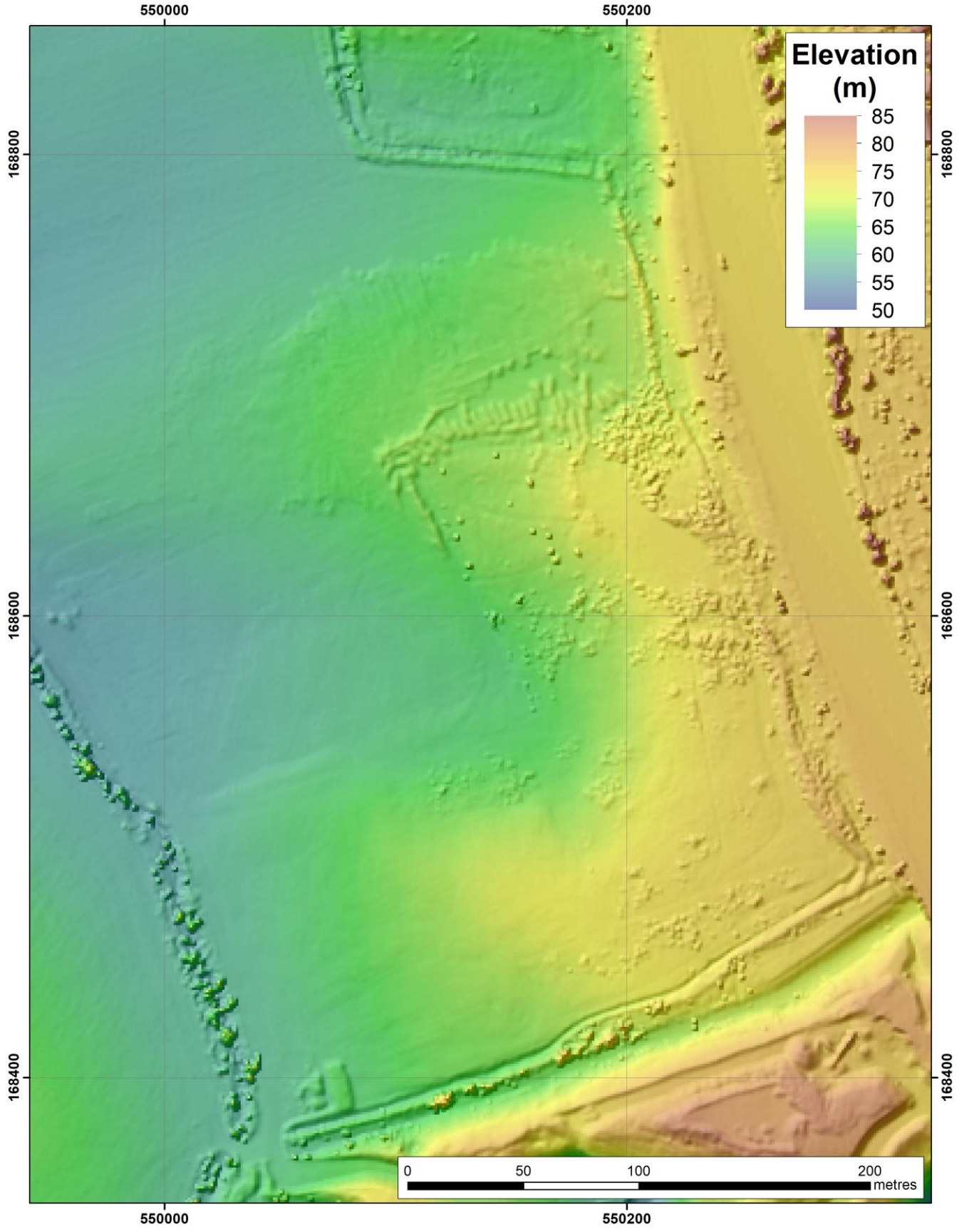

Figure 3 LIDAR elevation data acquired on 30 January 2018 for the Land to the North of Bournewood Sand and Gravel Limited site.

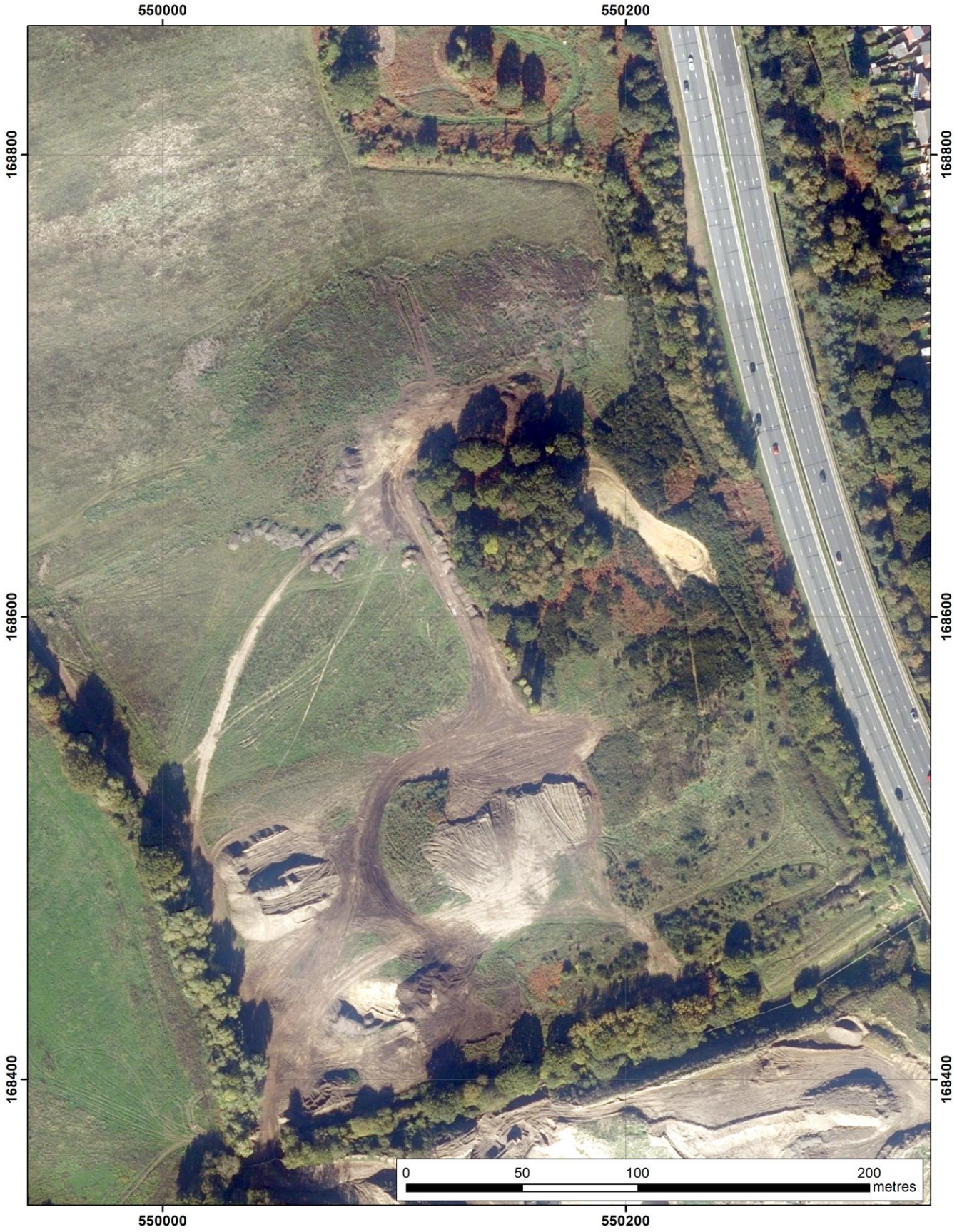

Figure 4 APGB aerial photography acquired on 21 October 2018 for the Land to the North of Bournewood Sand and Gravel Limited site. © Bluesky International.

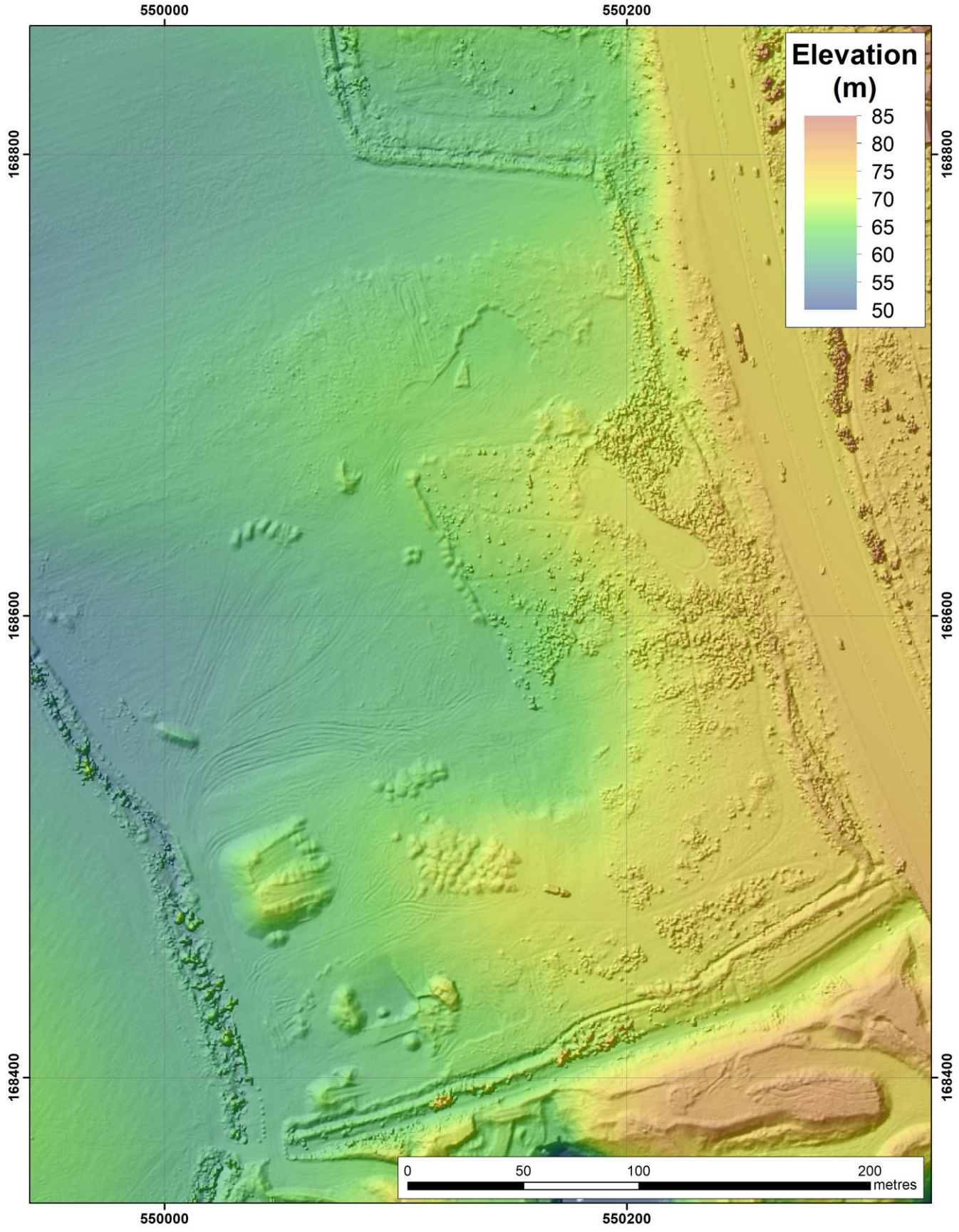

Figure 5 LIDAR elevation data acquired on 22 December 2018 for the Land to the North of Bournewood Sand and Gravel Limited site.

The methodology used for estimating volume change was as follows:

- 200 points were identified in the March 2015, January 2018 and December 2018 elevation data that were on unambiguous hard surfaces. The elevation at each of these points in each of these datasets was extracted. These points were split into two, those used to reduce the systematic error (the offset) between the elevation datasets and those used to test the relative accuracy of the datasets and generate confidence intervals (Figure 6).
- The systematic error was calculated using the average difference between the elevation datasets. From the systematic error calculations the March 2015 data were shifted by 0.010 m and the January 2018 data were shifted by -0.037 m.
- The root mean square errors (RMSE) from the points used to generate a relative accuracy between LIDAR datasets are in Table 2. The 99% confidence interval is three times the RMSE.
- Height change was estimated by subtracting the baseline elevation dataset from the more recent elevation data. The December 2018 LIDAR data were resampled to the 1 m, the same resolution as the March 2015 and January 2018 baseline data. The volume change was then estimated for the areas in Figure 7 from the material height change information.
- The 99% confidence interval for the volume was calculated by multiplying the number of pixels, by the area of each pixel and three times the RMSE (99% confidence interval per pixel).
- The area to carry out volume analysis were agreed between myself and John Radclyffe of Environment Agency Kent, South London and East Sussex by telephone conversation on 26 June 2019. The analysis areas were selected where change took place between 2015 and 2018. The areas were further refined using the December 2018 LIDAR and October 2018 aerial photography data by identifying sections that needed to be excluded, due to the presence of large vegetation such as trees and bushes. The areas to be included in the analysis are shown in Figure 7.

Table 2 RMSE values for change between LIDAR datasets

LIDAR datasets	March 2015 - January 2018	March 2015 - December 2018	January 2018 - December 2018
RMSE (m)	0.049	0.042	0.015

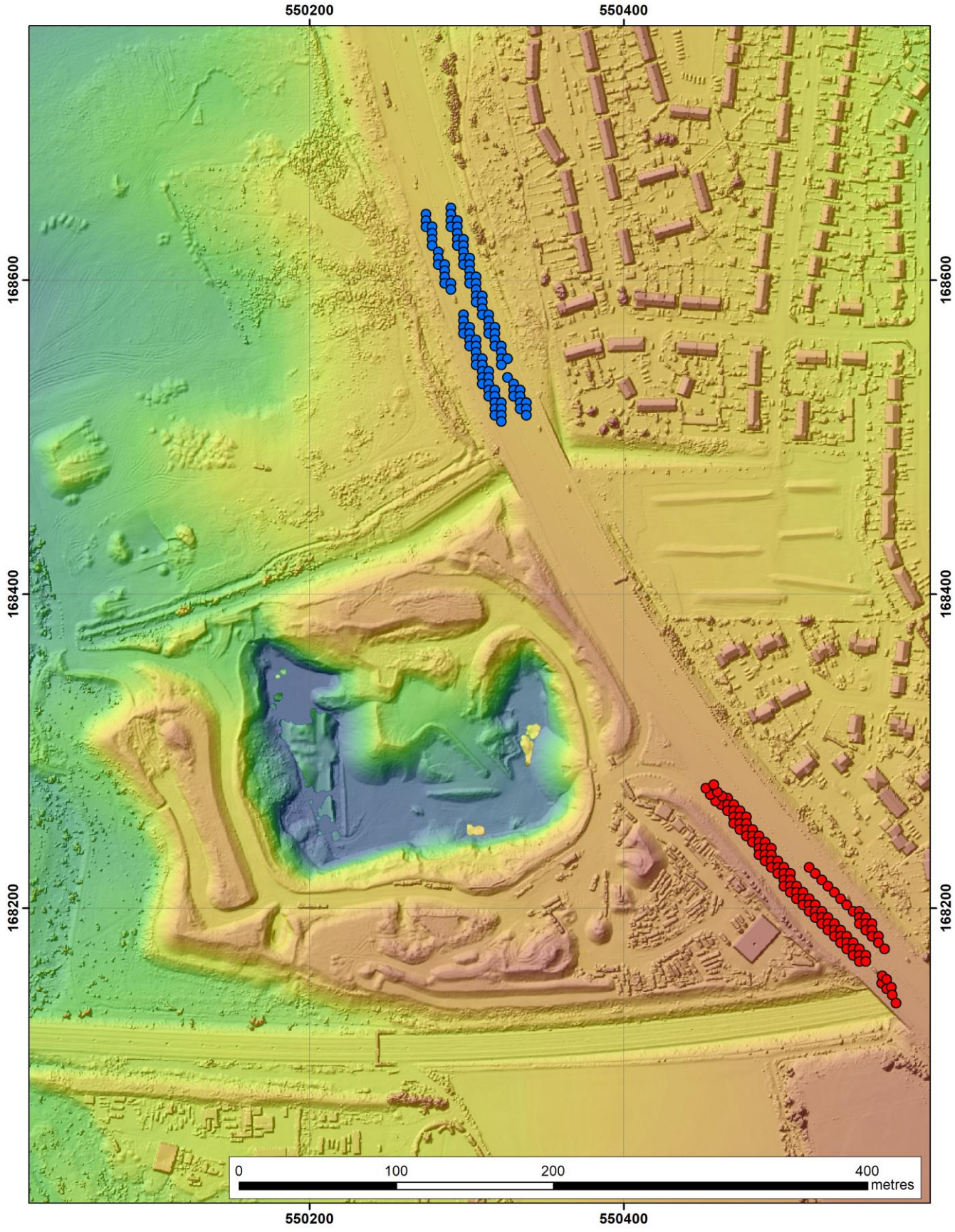

Figure 6 LIDAR sample points. Systematic error points in red, points used to estimate RMSE and confidence intervals in blue.

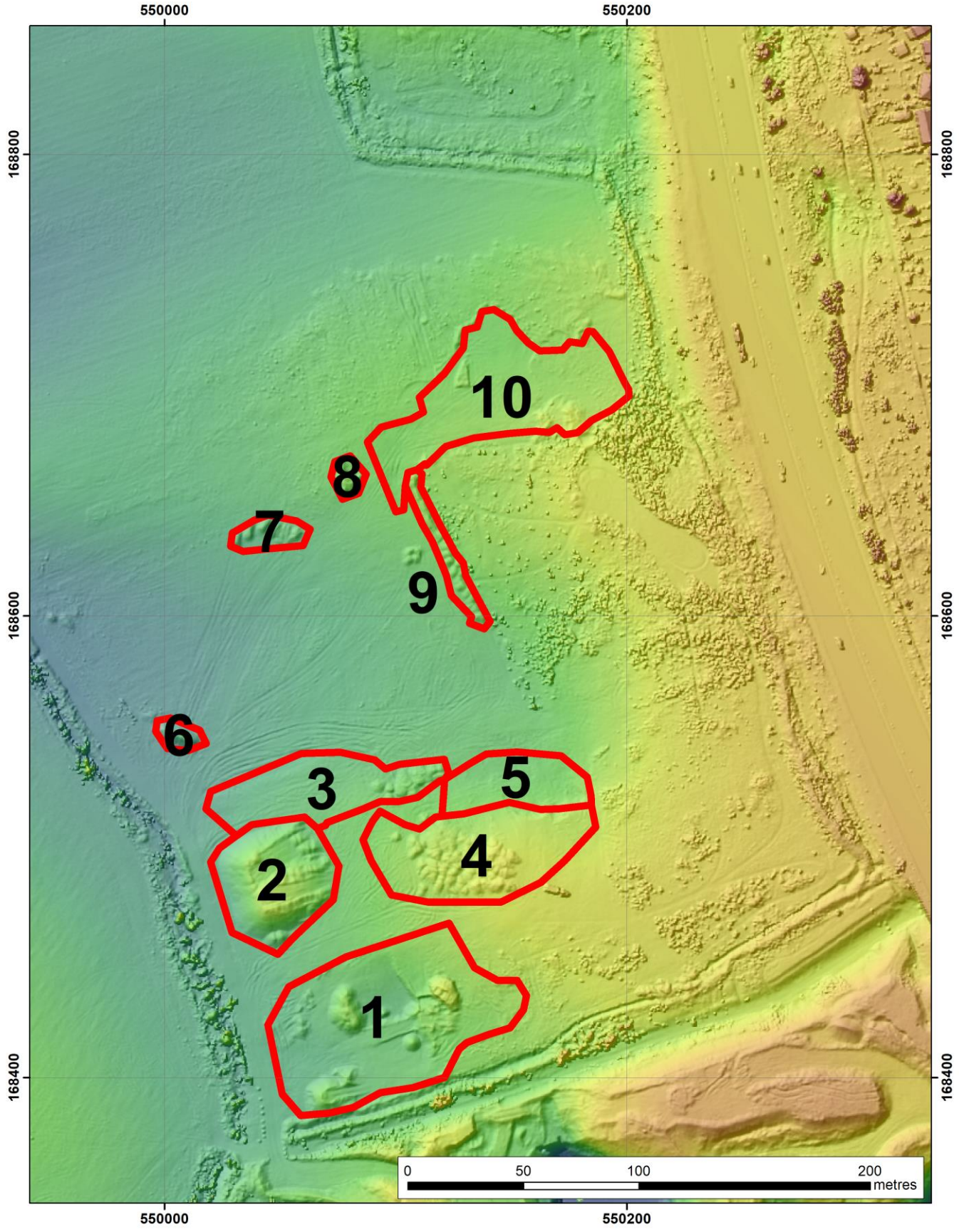

Figure 7 Analysis areas focussing where there was material change between 2015 and 2018 (red line). Other areas were excluded due to presence of large vegetation.

3 Change estimates – volume and elevation

Volume change calculations using LIDAR data are in Table 3 to Table 5.

Between 3 - 5 March 2015 and 30 January 2018 the total volume change, calculated using LIDAR data for the areas in Figure 7, was 5994 m^3. There is a 99% certainty that the volume change was at least 3083 m^3.

Between 3 - 5 March 2015 and 22 December 2018 the total volume change, calculated using LIDAR data for the areas in Figure 7, was 9060 m^3. There is a 99% certainty that the volume change was at least 6566 m^3.

Between 30 January 2018 and 22 December 2018 the total volume change, calculated using LIDAR data for the areas in Figure 7, was 3066 m^3. There is a 99% certainty that the volume change was at least 2176 m^3.

The volume change calculated provides an overall measurement of the net volume change of material at the site. However, it does not provide an indication of how the net volume change occurred, i.e. the total amount of material that was brought into the site and the total amount of material that was removed from the site. There is also no way of confirming using LIDAR data the nature of the material brought on to site or removed from the site. In this case, the volume calculated approximates the total volume of material brought onto the site minus the total volume of material removed from the site. The site is defined by the analysis areas in Figure 7.

Table 3 Volume change calculations between 3 - 5 March 2015 and 30 January 2018 for Land to the North of Bournewood Sand and Gravel Limited. Analysis carried out for areas in Figure 7.

Area	Volume change (m^3)	Lower 99% confidence interval (m^3)
1	1096	265
2	59	-273
3	1130	810
4	1496	1035
5	183	-13
6	-3	-33
7	-18	-74
8	28	1
9	150	71
10	1873	1294
Total	**5994**	**3083**

Table 4 Volume change calculations between 3 - 5 March 2015 and 22 December 2018 for Land to the North of Bournewood Sand and Gravel Limited. Analysis carried out for areas in Figure 7.

Area	Volume change (m^3)	Lower 99% confidence interval (m^3)
1	-1202	-1914
2	6671	6386
3	1355	1081
4	2594	2199
5	-681	-849
6	225	199
7	129	81
8	109	86
9	269	202
10	-409	-905
Total	**9060**	**6566**

Table 5 Volume change calculations between 30 January 2018 and 22 December 2018 for Land to the North of Bournewood Sand and Gravel Limited. Analysis carried out for areas in Figure 7.

Area	Volume change (m^3)	Lower 99% confidence interval (m^3)
1	-2298	-2552
2	6612	6510
3	225	127
4	1098	957
5	-865	-925
6	228	219
7	147	130
8	81	73
9	120	96
10	-2282	-2459
Total	**3066**	**2176**

Maps of the elevation change are given in Figure 8 and Figure 10.

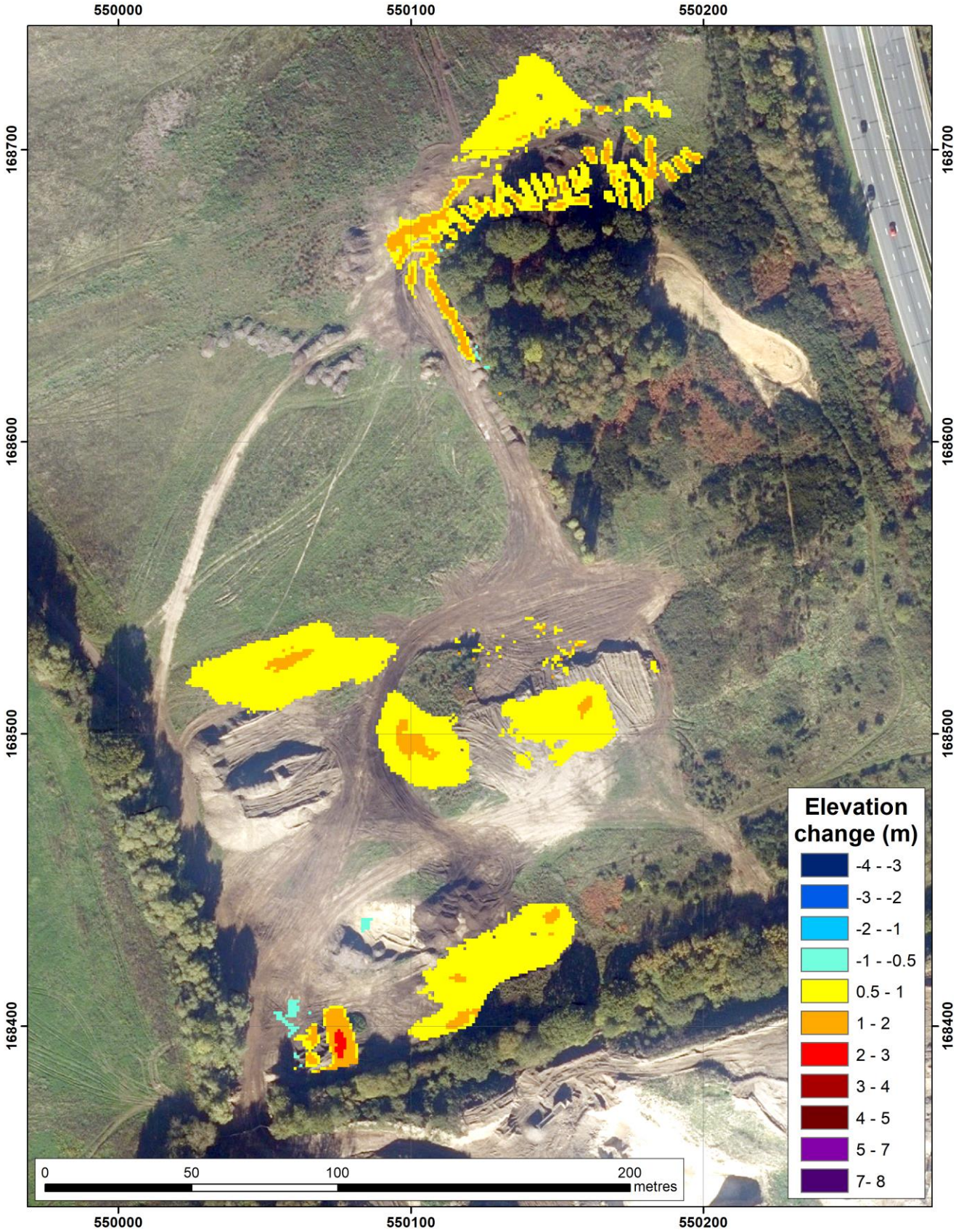

Figure 8 2018 aerial photography of the Land to the North of Bournewood Sand and Gravel Limited site with elevation difference between 3 - 5 March 2015 and 30 January 2018 overlaid. Analysis carried out for areas in Figure 7.

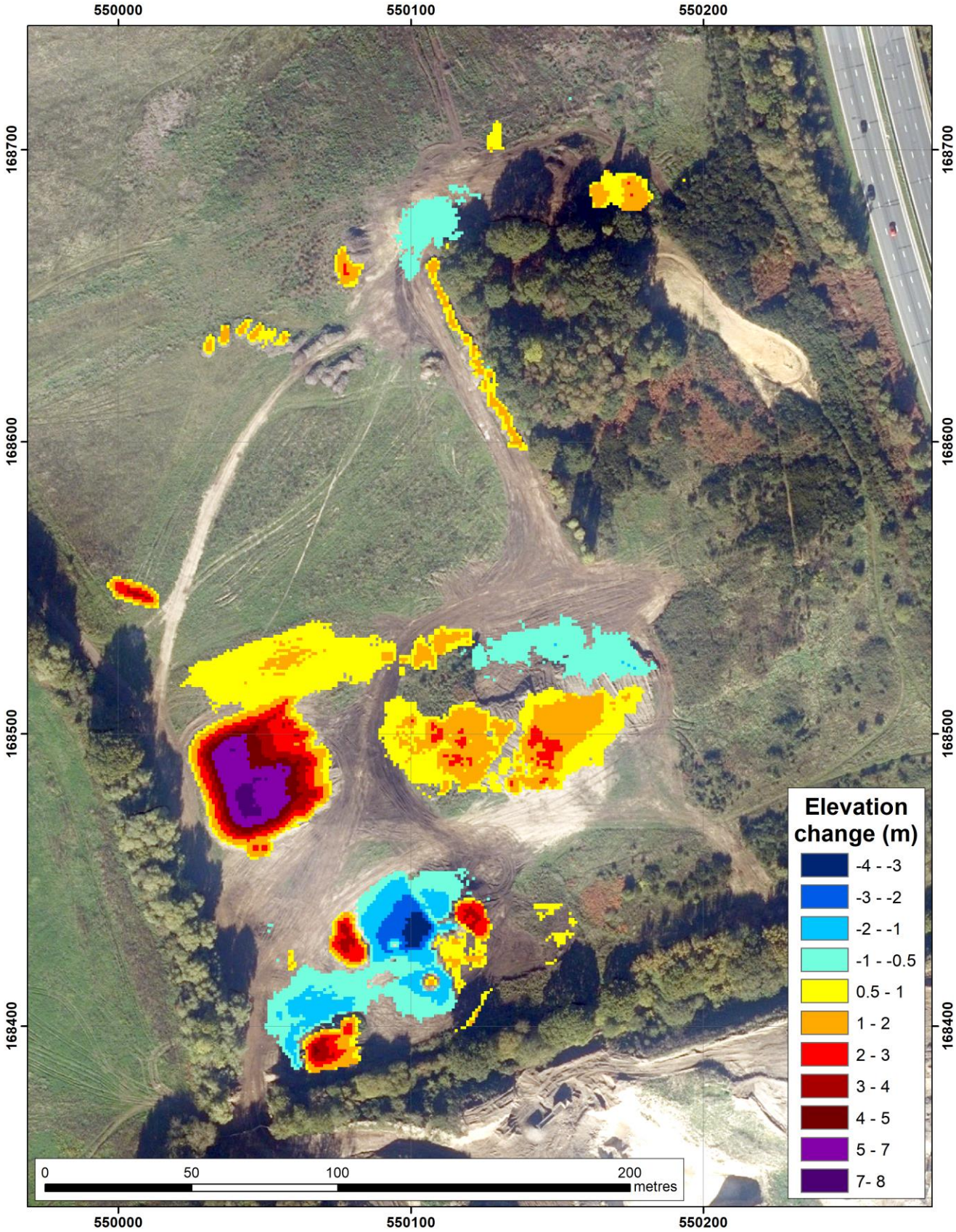

Figure 9 2018 aerial photography of the Land to the North of Bournewood Sand and Gravel Limited site with elevation difference between 3 - 5 March 2015 and 22 December 2018 overlaid. Analysis carried out for areas in Figure 7.

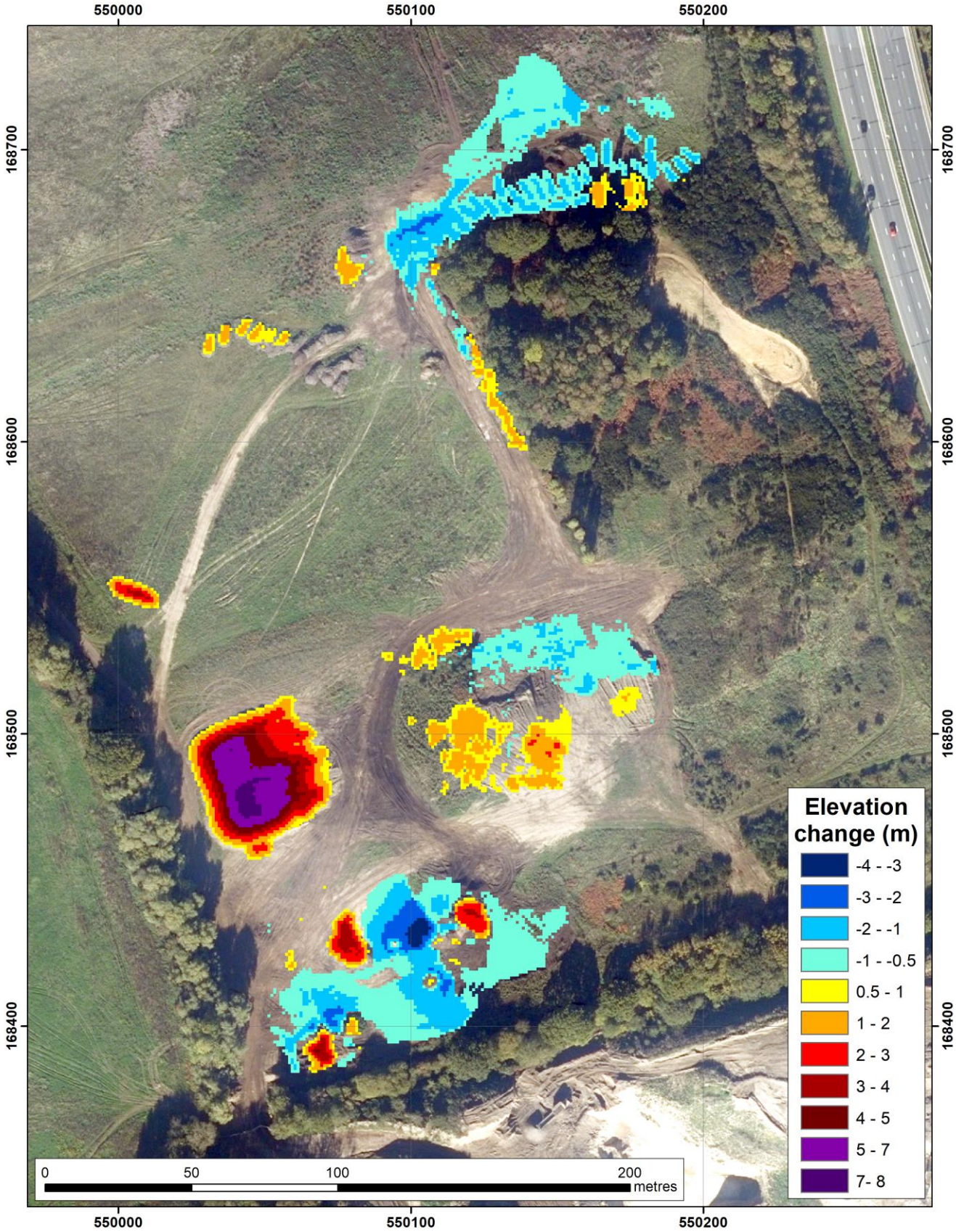

Figure 10 2018 aerial photography of the Land to the North of Bournewood Sand and Gravel Limited site with elevation difference between 30 January 2018 and 22 December 2018 overlaid. Analysis carried out for areas in Figure 7.