ASSESSMENT OF THE RED BRAE COLLAPSE ON THE FLOODING MECHANISM OF 30TH DECEMBER 2015

RPS, August 2019

FINAL REPORT

ASSESSMENT OF THE RED BRAE COLLAPSE ON THE FLOODING MECHANISM DURING 30th DECEMBER 2015

Background

In an article in the Ballater Eagle (page 48, Summer 2019 edition), Ballater Flood Group (BFG) raised concerns that the Ballater FPS reporting does not accurately describe the sequence of events as they occurred during the flood event of the 30th December 2015 (as a consequence of Storm Frank). The BFG state that:

- The lateral force of the water undercut the face of the Braes, creating a 'cornice'. A large section of this fractured, falling into and obstructing the main channel.
- From the evidence available, it is most likely that the collapse of the 'Red Braes' resulted in a temporary water flow restriction, permitting a back up of water and a diversion of flow towards the breach point (where the informal flood defence embankment along the golf course breached adjacent to the 14th tee).

Purpose

The purpose of this report is to undertake an assessment of the Red Brae collapse to determine the impact of the collapse on the flooding mechanism in Ballater, during the 30th December 2015 flood event. This assessment is undertaken in two stages – defining the extent of the Red Brae collapse and the potential for the collapse to divert flow towards the golf course.

Defining the extent of the Red Brae collapse

The Red Brae is located along the right bank of the River Dee, on the opposite side of the river to Ballater Golf Course (see Figure 1). The Red Brae is characterised by steep slopes, with the top of bank approximately 8 to 10 metres above the river channel (see Figure 2). The channel in the vicinity of the Red Brae and surrounding area, is dominated by erosional processes, with scour 'leading to the failure of an extensive length of high alluvial river terrace' (cbec, 2018).

RPS undertook a topographical survey of the River Dee in the summer of 2017, as part of the Ballater Flood Protection Study. The location of the cross-sections recorded during this survey is shown in Figure 3. A review of this survey data shows that the most upstream cross-section with a significantly high right bank (in comparison to the left bank) is RD61 with the most downstream cross-section being RD68 (Figure 3). This indicates that the length of the reach known as the Red Brae is over 400 metres.

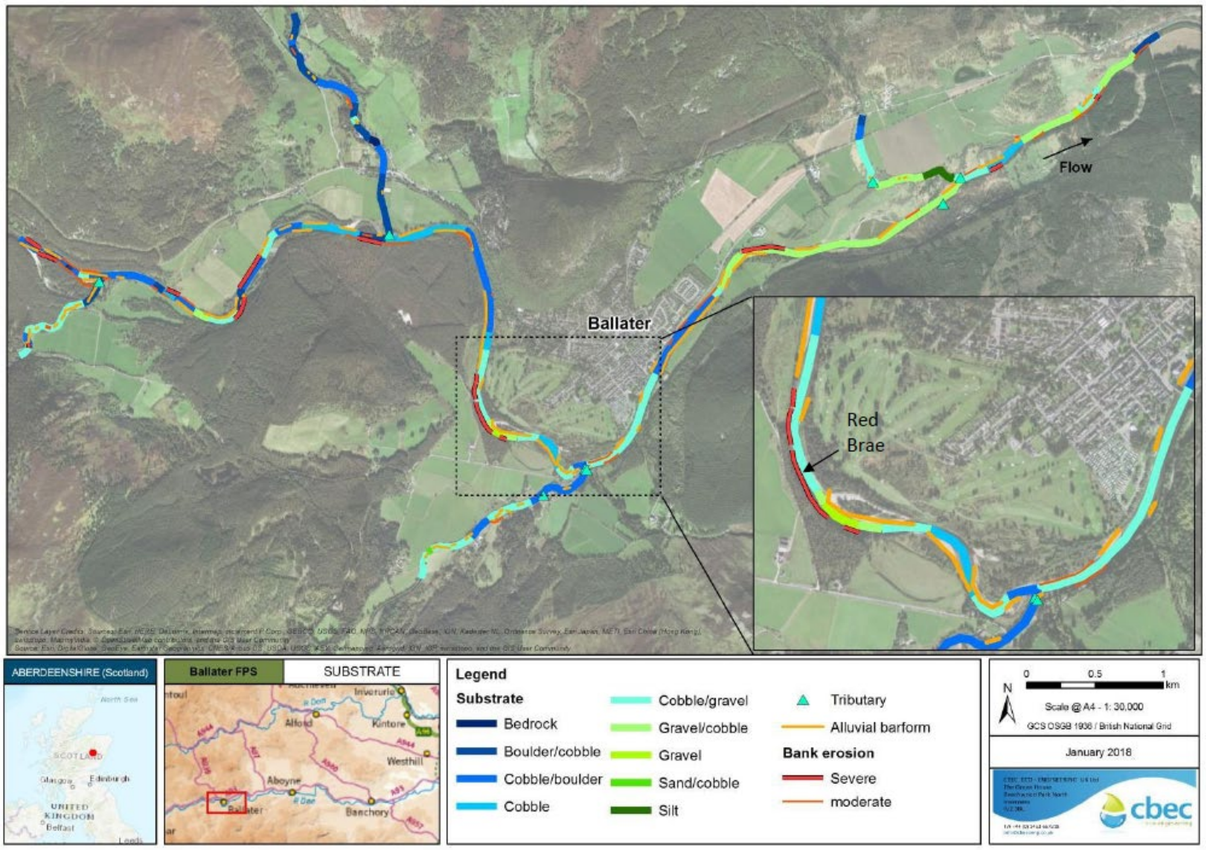


Figure 1 Location of Red Brae, Ballater and identification of sediment dynamics (Ballater Flood Protection Scheme, Geomorphic Process Model and Review of Morphological Impacts. cbec eco-engineering, January 2018).

Figure 2 Photograph of the Red Brae, River Dee (taken at cross-section RD63).

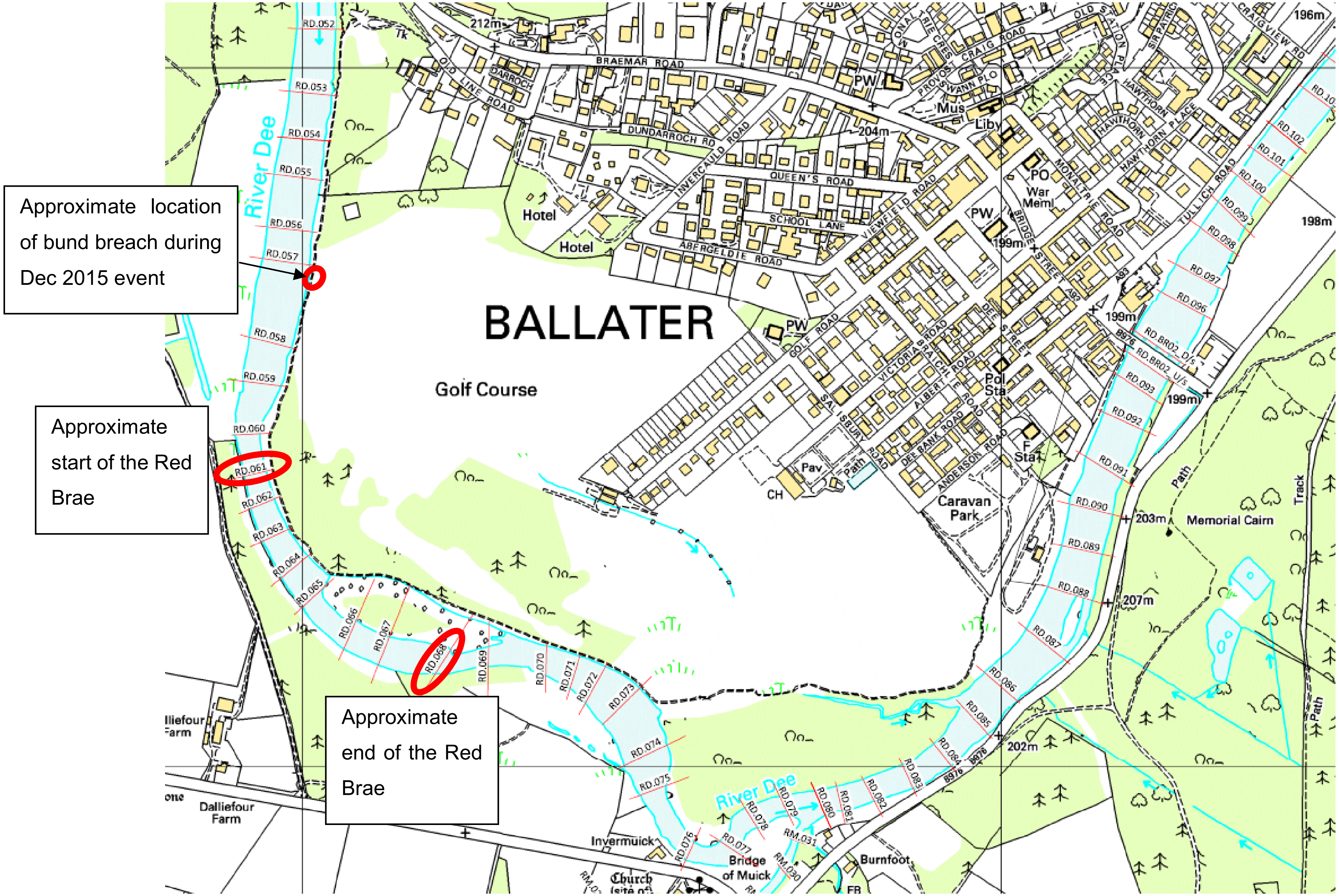


Figure 3 **Location of cross-sections recorded during 2017 topographical survey (Figure 11 to Figure 13)**

It is widely reported that the Red Brae suffered a collapse as a consequence of the flood flows within the River Dee during the 30th December 2015 flood event. In order to determine the extent of the collapse, the James Hutton Institute (JHI) undertook an analysis (July 2019) of LiDAR, topographical survey information and aerial images from before and after the 30th December 2015 flood event at two locations on the River Dee – cross-section RD63 and cross-section RD57 (Figure 3).

Figure 4 compares cross-sections that JHI extracted from LiDAR data recorded in 2011 and 2016 (black and blue lines respectively) at a representative point along the Red Brae (cross-section RD63). The right bank of the River Dee (Red Brae) is shown on the left of Figure 4. This shows that the Red Brae receded by approximately 13 metres at river level and by approximately 8 metres at the top of bank. Both of these cross-sections incorporated the river level when the LiDAR data was recorded. RPS undertook a topographical survey of the River Dee in the summer of 2017, as part of the Ballater Flood Protection Study. The relevant cross-section is shown in red in Figure 4, which is comparable to the other post-flood event cross-section (from the 2016 LiDAR). It should be noted that the 2017 cross-section incorporates the river bed level (and the not the river water level) at the time of the survey. Figure 4 also shows the width of the River Dee at cross-section RD63 changed from approximately 40 metres in 2011 to over 50 metres in 2016 and 2017.

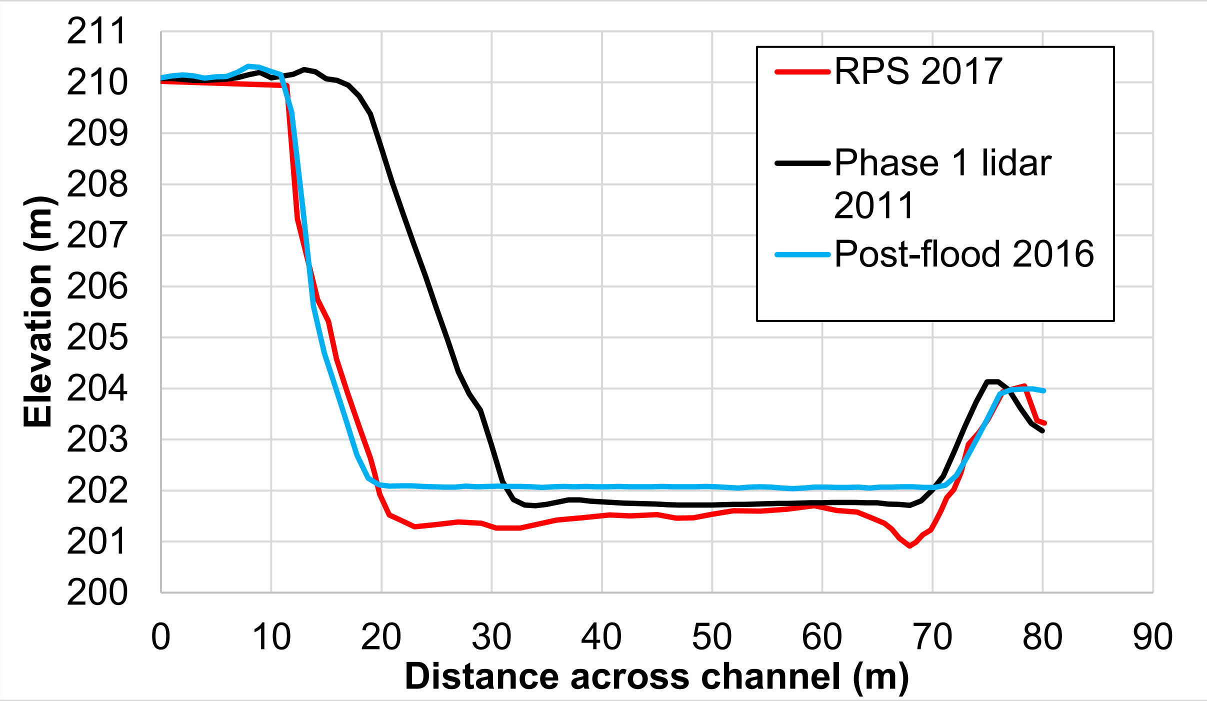


Figure 4 **Comparison of River Dee cross-sections (RD63) at the Red Brae.**

Figure 5 and Figure 6 show aerial images of the area where cross-section RD63 is located, and demonstrate how the channel has widened between October 2015 and April 2016 when the images were recorded. These images, in addition to the cross-sections in Figure 4, suggest that the changes in the channel geomorphology at this location occurred as a result of the 30th December 2015 flood event.

Figure 5 **Aerial image of area where cross-section RD63 is located, before December 2015.**

Figure 6 **Aerial image of area where cross-section RD63 is located, after December 2015.**

Figure 7 compares cross-sections that JHI extracted from LiDAR data recorded in 2011 and 2016 (black and blue lines respectively) at the point where a breach of the informal flood embankment occurred during the 30th December 2015 flood event (cross-section RD57). Figure 3 shows that this is located upstream of where the Red Brae is considered to be located, by approximately 300m. The right bank of the River Dee is shown on the left of Figure 7, and is less than 3m high (in comparison with over 8m at RD63). Both of these cross-sections incorporated the river level when the LiDAR data was recorded. The relevant cross-section recorded during the RPS 2017 survey is shown in red in Figure 7. It should be noted that the 2017 cross-section incorporates the river bed level (and the not the river water level) at the time of the survey. Figure 7 shows that there was an insignificant change in the river profile between 2011 and 2017, and therefore it is concluded that there was no collapse during the 30th December 2015 flood event at this location on the river.

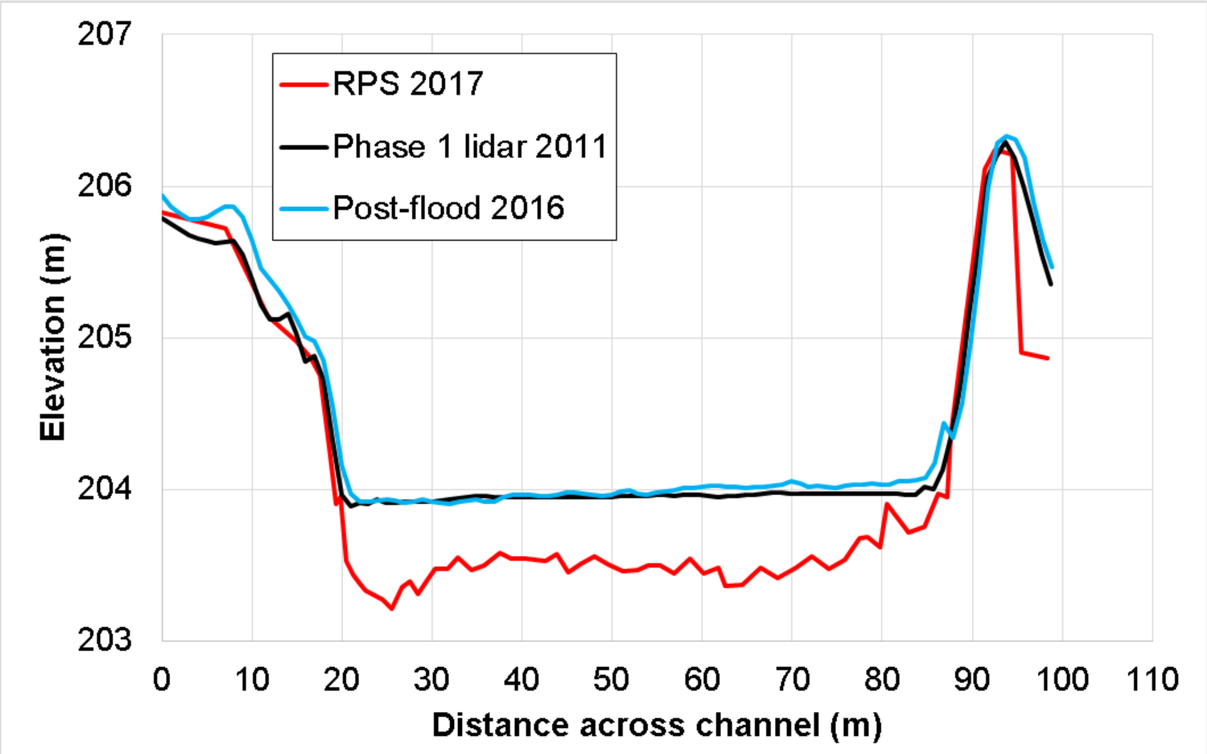


Figure 7 Comparison of River Dee cross-sections (RD57) at the Red Brae.

Figure 8 **Aerial image of area where cross-section RD57 is located, before December 2015.**

Figure 9 **Aerial image of area where cross-section RD57 is located, after December 2015.**

Potential for the collapse to divert flow towards the golf course

The only channel data available prior to the 30th December 2015 flood event in based on the LiDAR recorded in 2011. On assessment of the aerial images between 2012 and 2015, it is likely that any collapse during this period was minimal, as the terrace was semi-vegetated with boulder toe armour with no significant flood events. Assuming that the channel dimensions remained similar from 2011 until December 2015, and that the change in the channel dimensions (as shown in Figure 4) were as a consequence of the flood event, then this means that an 8 to 9 metre high by 8 to 13 metre wide column collapsed into the Dee. Based on digital elevation model (DEM) differencing undertaken by JHI (see Figure 10), the total volume of sediment eroded from the Red Braes terrace is 26,271.5 m^3 (error: +/- 525.4 m^3), with the vast majority of this as a consequence of the 30th December 2015 flood event. Appendix A shows the DEM of difference map showing the areas of erosion (shown by red and yellow) and deposition. It should be noted that areas showing change in the wetted areas of channel should be treated with caution but the changes on the dry areas of bank (including the Red Brae terrace) and floodplain are considered to be reliable.

A more simplified assessment, based solely on the estimated dimensions of the Red Brae terrace (i.e. on average 8.5m tall along a length of 442m, having receded an average of 10m) then this equates to a total volume of 37,570m^3 which potentially collapsed into the Dee. The two different methods produce significantly different estimated volumes of material, however, it can be said that they both support the case for a very large volume of material being eroded from the Red Brae in December 2015.

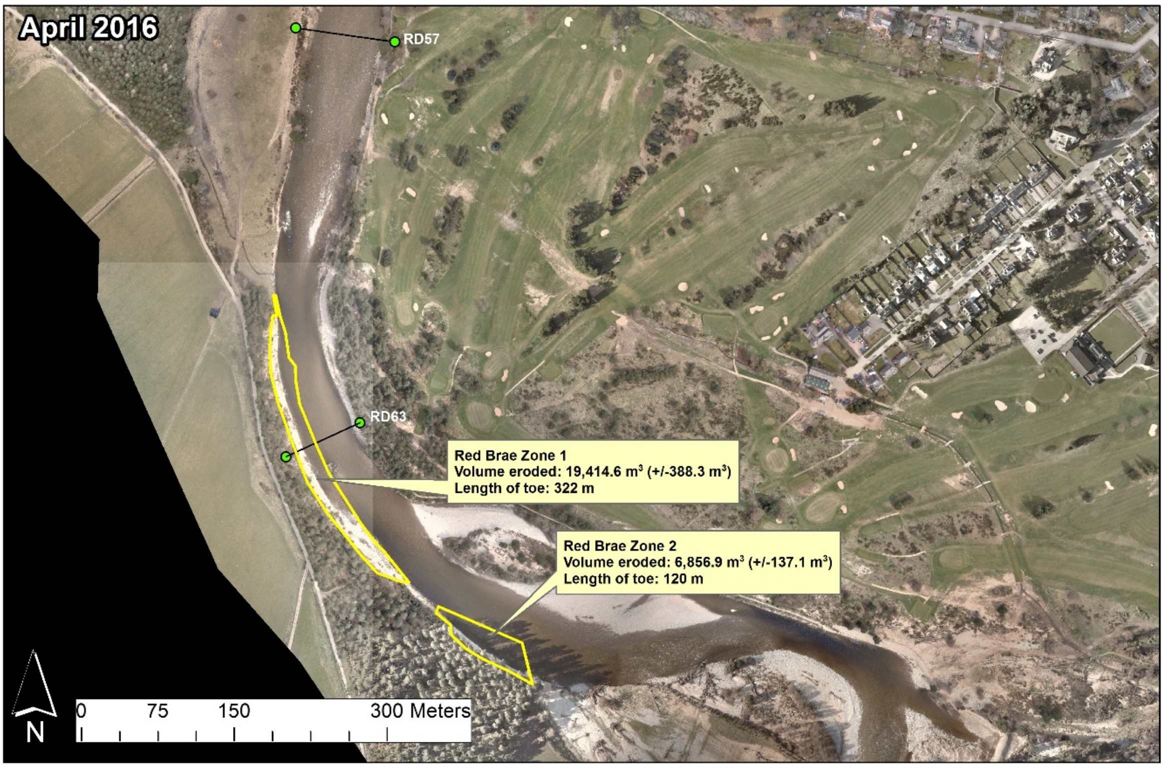


Figure 10 **Estimated volume of eroded material at the Red Brae following December 2015**

The terrace of Red Brae is composed of sands, gravels, cobbles and boulders of glacial origin. There is no data available to determine the proportions of these materials in the terrace but it is likely, based on visual observations of the terrace as it is now, that a massive volume of the collapsed material would have been made up of sands and gravels. The river would have had more than enough competence and transport capacity to shift this material hundreds of metres or kilometres downstream beyond the reach. The BFG have stated that this has been confirmed by sedimentary analysis which established that Red Braes deposits spread extensively downstream). The coarser boulders and cobbles would have travelled less far. JHI consider that due to the magnitude of the 30th December 2015 event, it is unlikely that the collapsed material could have accumulated to form enough of a restriction to create a backwater effect and this is a phenomenon unheard of in UK rivers.

Prior to December 2015, the width of the River Dee was approximately 40 metres. Even if the collapsing column remained intact (which is unlikely as discussed above), it would only reach across approximately one quarter to one third of the river channel. Consequently, it would not be possible for the collapse of the Red Brae to obstruct the main channel, as stated by the BFG.

The BFG have stated that the collapse permitted ‘a back up of water and a diversion of flow towards the breach point’ (where the informal flood defence embankment along the golf course breached adjacent to the 14th tee). Even if the collapse obstructed up to a third of the channel, this would be insufficient to permit a back up flow and divert water towards the golf course, as the vast majority of the flow would be able to bypass the restriction via the remaining two-thirds of the channel.

Figure 3 shows the reported location of the breach within the informal flood defence embankment. This is located close to the 14th tee of the Golf Course, between cross-sections RD57 and RD58 (Figure 11 and Figure 12 respectively), where the current height of the right bank above river level is much reduced in comparison to RD63 as shown in Figure 13 (and therefore the impact of collapse further diminished assuming a similar height of bank prior to December 2015). The height of the right bank above the recorded level at RD58 is approximately 2.5m. It is noted that the breach location is approximately 300 metres upstream of cross-section RD61 (which is considered to be the start of the Red Brae) meaning that the collapse would have had to produce a significant backwater effect in order to be the main contributing factor to the breach in the informal flood defence and the diversion of flows across the golf course.

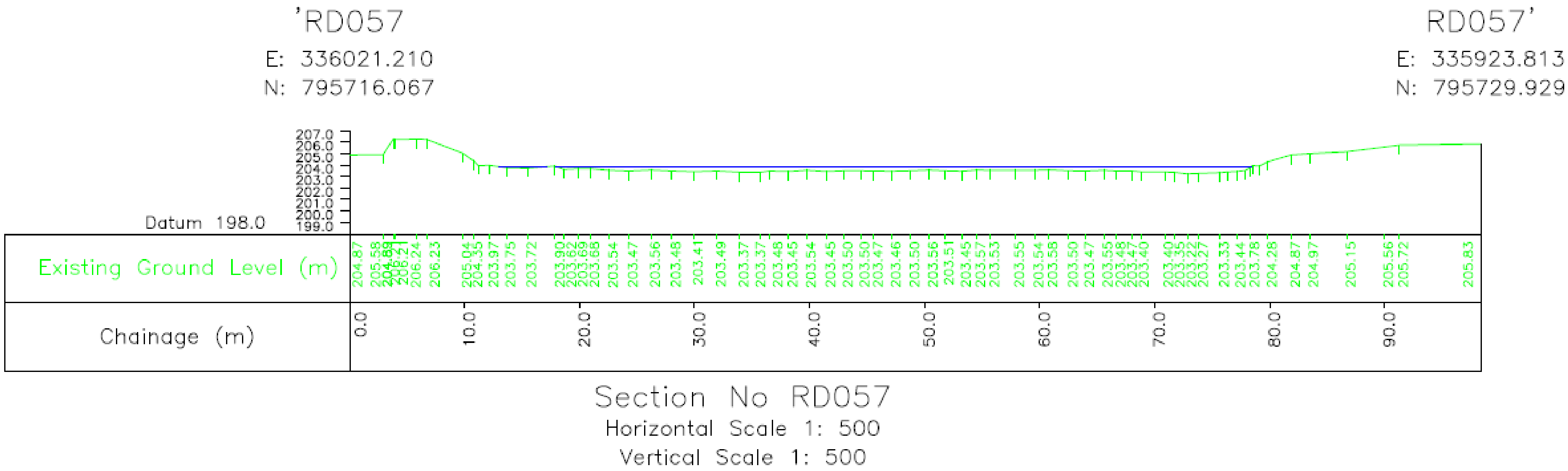


Figure 11 **Cross-section RD57 recorded during the 2017 topographical survey**

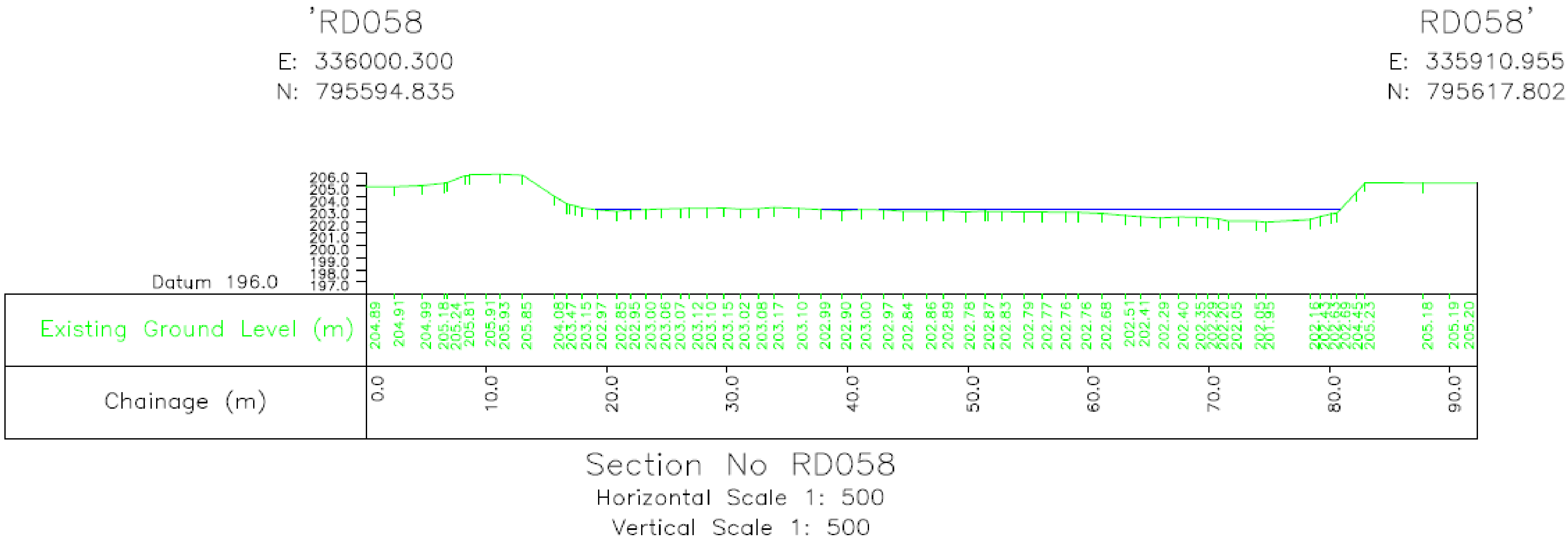


Figure 12 **Cross-section RD58 recorded during the 2017 topographical survey**

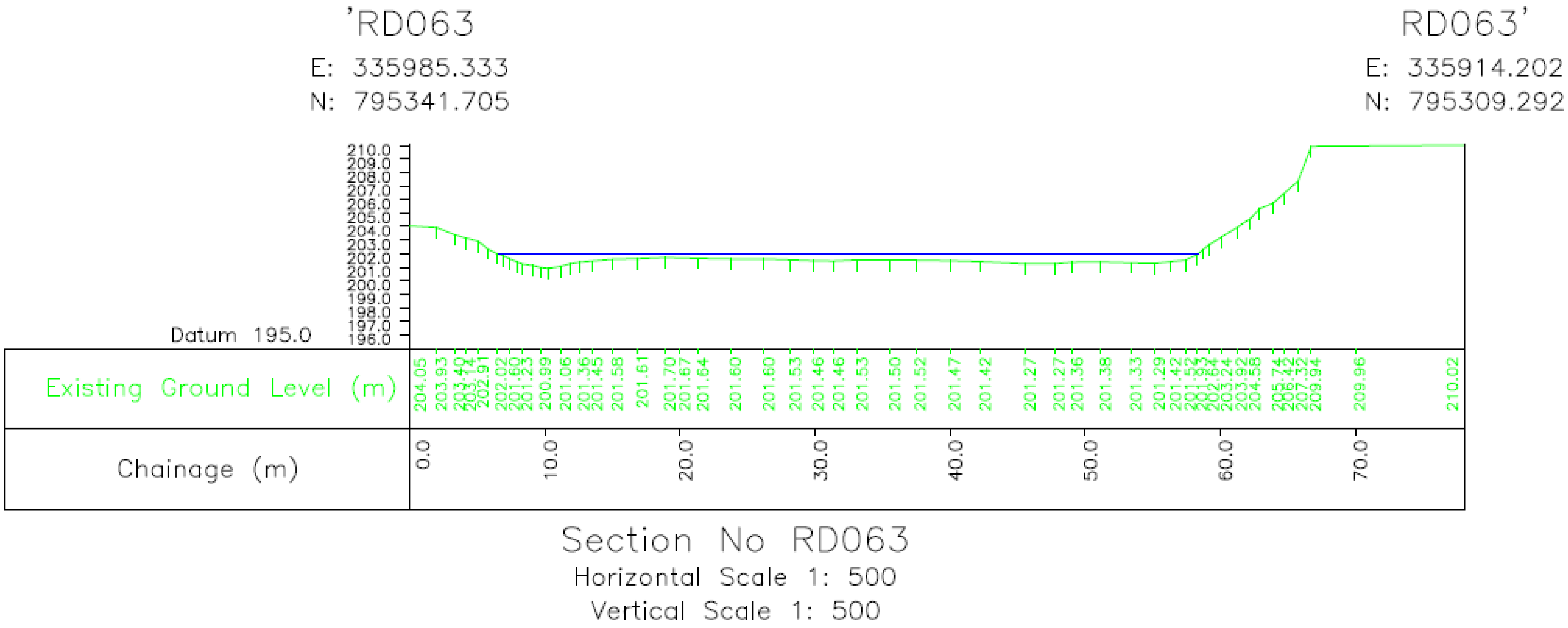


Figure 13 **Cross-section RD63 recorded during the 2017 topographical survey (ref: Figure 2)**

It should be noted that the Ballater FPS Feasibility Report does reflect the flow direction that has been described by the BFG i.e. that flood water flowed across the golf course from the River Dee at the 14th tee of Ballater Golf Club. Figure 3.28 in the Feasibility Report (which is shown in Figure 14 below) shows that the hydraulic model used in the study, which was constructed based on the 2017 survey information, simulates flow leaving the main channel and entering the floodplain from cross-section RD54 (which is located just upstream of the 14th tee) to cross-section RD82. This shows that the flood water from the River Dee flows naturally from the river towards the golf course (and the informal flood defence) and is not dependent on a collapse of the Red Brae causing a restriction in the channel (as this was not included in the model). It should also be stated that even if the breach did not occur, a similar flooding mechanism would have occurred in any case, as the informal flood defence was determined to have a standard of protection of 20% AEP (1 in 5 year return period), as during the simulated 1 in 10 year return period the bund was overtopped (Hydraulics Report, Section 3.6.2). On 30th December 2015, the peak flood levels were significantly higher than the crest of the informal flood defence, meaning that the embankment would have been overtopped even if the breach hadn't occurred.

Figure 14 also shows water flowing from the floodplain into the River Dee upstream of the Royal Bridge. This is in agreement with the comment from the BFG in the Ballater Eagle 'that the Golf Club flood waters were flowing towards rejoining the main channel and NOT escaping from it'.

It is not considered beneficial to determine the potential of the collapse to divert flows via morpho-dynamic modelling. This is because there is no topographical information of the river channel prior to the 30th December 2015 flood event available (and therefore it is not possible to establish a baseline); there is no pre-flood sediment data from the Red Brae terrace or bed of the River Dee and there is no data to calibrate such a model (e.g. a time series of morphological change or reliable before/after riverbed topography). Consequently, there would be little or no confidence in the accuracy of the outputs from any such model.

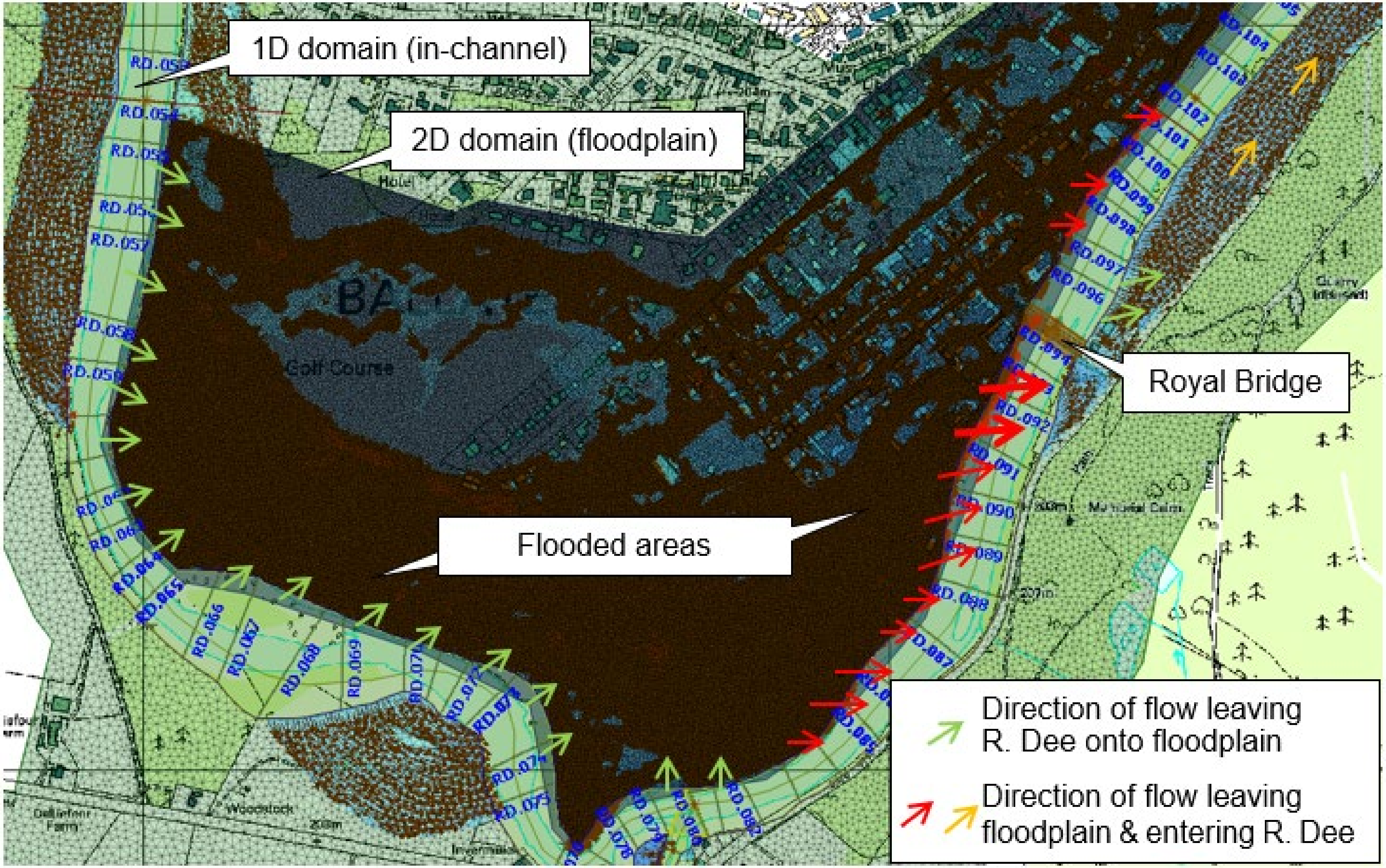


Figure 14 **Overview of the interaction of flows between the River Dee and its floodplain, during a 0.5% AEP (1 in 200 year) flood event.**

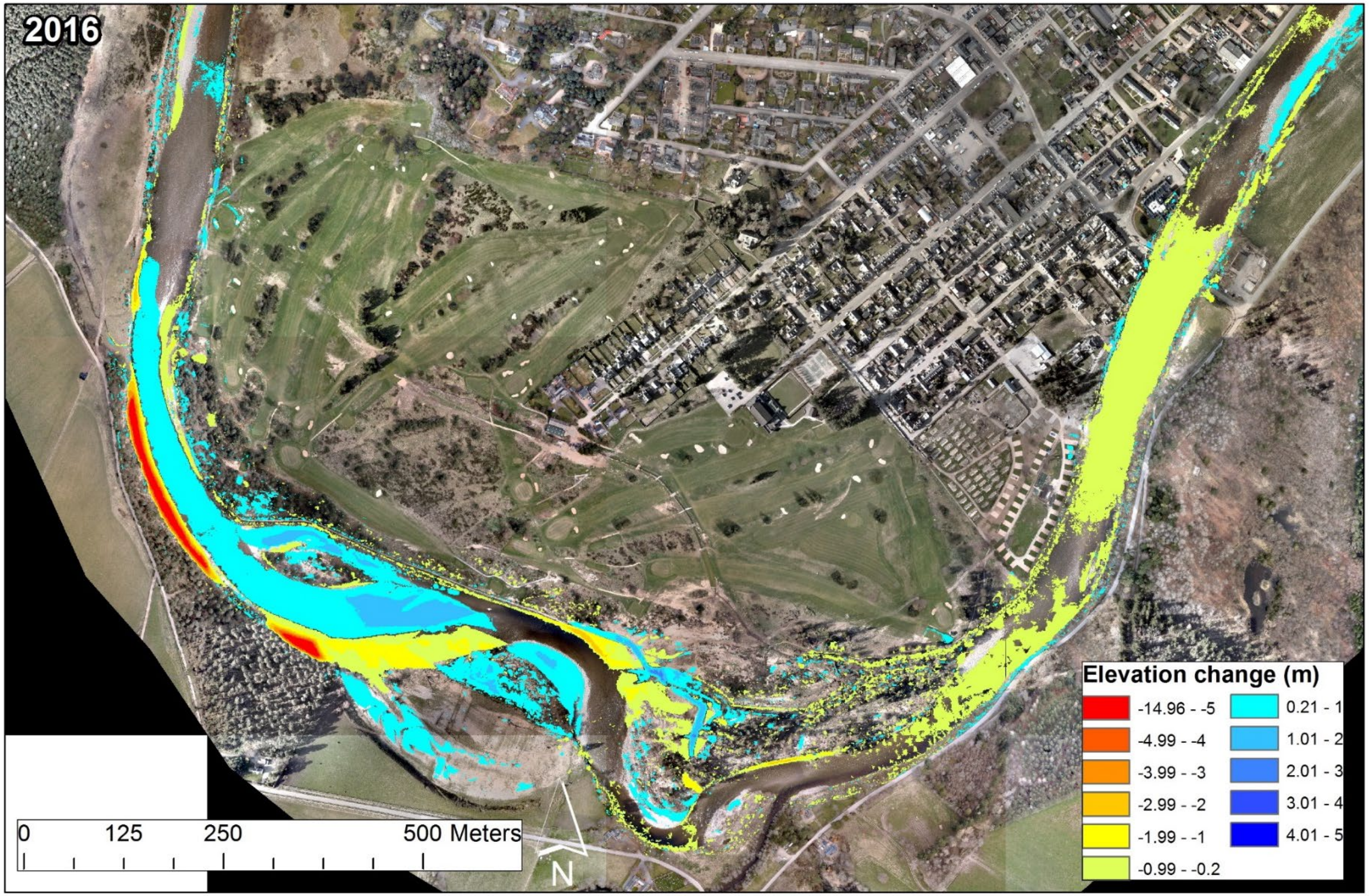
Summary

RPS agree with the BFG that flood water flowed from the main River Dee channel towards the Golf Course during the 30th December 2015 event. However, RPS disagree that this flooding mechanism is a result of the collapse of the Red Brae embankment during that event.

RPS have reviewed the BFG article in the Summer 2019 edition of the Ballater Eagle, and believe that the above assessment addresses all of the concerns identified by the BFG in relation to the accuracy of the Ballater FPS reporting of the 30th December 2015 flooding mechanisms. RPS request that if there are any further concerns with the accuracy of the reporting, that the specific elements of the reports are identified (Hydrology Report, Hydraulics Report and Feasibility Report which are available on http://ballater-fps.com/supplementary-reports/) in order to facilitate resolution of any remaining issues.

APPENDIX A

DIGITAL ELEVATION MODEL (DEM) DIFFERENCE MAP



Digital elevation model of difference based on subtraction of the 2016 LIDAR elevation data by the 2011 LIDAR elevation data. Yellow, orange and red colours highlight erosion (i.e. surface lowering) and the blue colours show deposition (surface raising). Only changes greater than 0.2 m are shown due to error in the LIDAR data. Note that erosion or deposition changes within the wetted areas of river channel are not considered reliable.