

Surveys of Uamh Bheag and Uamh Bheag East Top

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The Team:

Surveyors – Chris Crocker, Graham Jackson, Dave Marshall & Fiona Marshall

1) Introduction

G&J Surveys has agreed a project with the Scottish Mountaineering Trust (SMT) to measure accurate heights for several Scottish mountains. The aim of the project is the resolution of anomalies that currently exist in several lists of the hills that are of interest to both the Scottish Mountaineering Club (SMC) and the wider hillwalking community. Two such lists are the Donalds and the Grahams. Donalds are hills in the Scottish Lowlands, that is south of the Highland Boundary Fault, that are 2000ft or over. The list first appeared in the 1953 edition of Munro's Tables and has been revised on several occasions since. It was later recognised that the Highland Boundary Fault included the hills in Glen Artney which lies just SW of the village of Comrie and the hills in this survey report lie in that glen. Grahams are hills in Scotland of height between 2000 feet and 2500 feet, but with 150 metres or more of drop. This list was published by Fiona Torbet (nee Graham) in the November 1992 issue of The Great Outdoors, the same year as the publication of The Relative Hills of Britain by Alan Dawson. Fiona Torbet's list was not identical to the subset of Marilyns termed the Elsie's in The Relative Hills of Britain, but the two authors met and decided to unify the lists. The unified list was to be called The Grahams, but the data used would be taken from Alan Dawson's book. Upon Fiona Torbet's death Alan became the sole list author.

Uamh Bheag (Hill number 1644, Grid Ref NN691118) and Uamh Bheag East Top (Hill number 7153, Grid Ref NN696119) are shown on OS 1:50000 Map 57 and OS1:25000 Maps OL47W 368W. Both hills have a spot height of 664m on the 1:25000 Map but only Uamh Bheag has a 664m spot height on the 1:50000 Map. The 1:10000 Map also shows both summits with a 664m spot height. The trig point on Uamh Bheag East Top is given a height of only 662m on all maps, the 664m spot height appearing on the larger more northerly ring contour. Consequently, it is not clear from OS maps which hill is the higher and therefore which is the Graham and Donald. The purpose of this survey was to obtain accurate heights for the summits of Uamh Bheag and Uamh Bheag East Top using a survey grade Leica Viva GS 15 Professional GNSS (Global Navigation Satellite System) receiver, and then obtain OS verification and report the results to the SMC.

2) Equipment used and Conditions for Survey

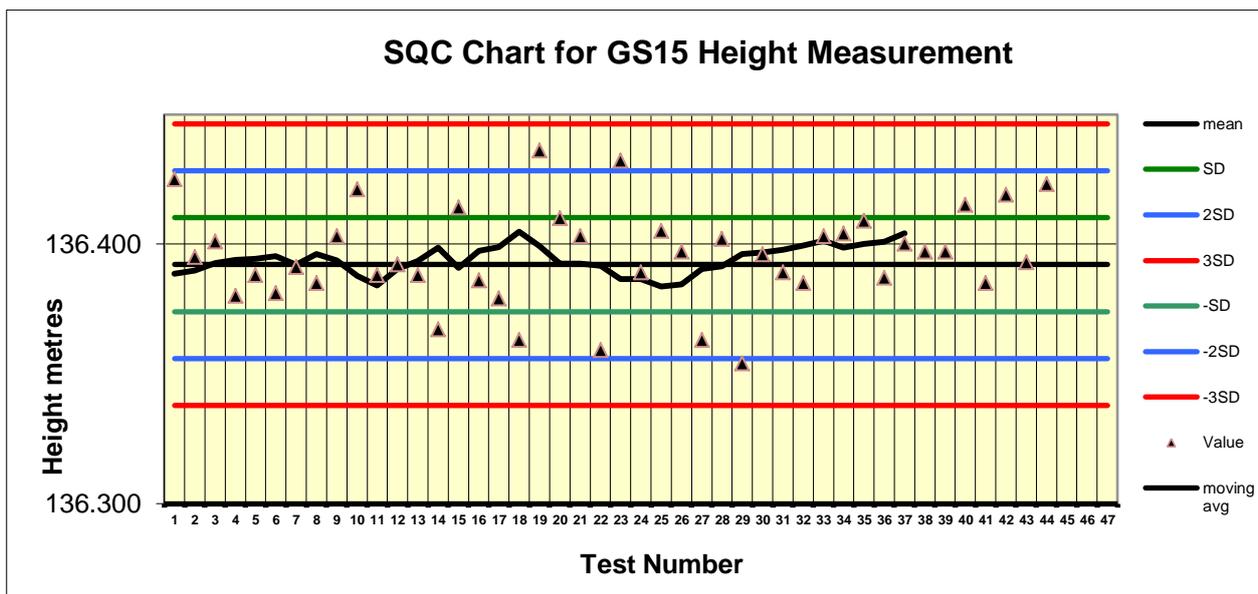
The summit positions were identified using a Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" E-staff extendable to 5m as required by Ordnance Survey.

Absolute heights were measured using a Leica Geosystems Viva GS15 Professional receiver. This instrument is dual-frequency and multi-channel, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receives two signals (at different frequencies) from each of these satellites. The latter feature reduces inaccuracies that result from atmospheric degradation of the satellite signals. As a stand-alone instrument it is capable of giving position and height to an accuracy of about two metres and five metres respectively. Despite the on-board features of the Viva GS15 receiver, there are still sources that

create residual errors. To obtain accurate positions ($\pm 0.01\text{m}$) and heights ($\pm 0.05\text{m}$), corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from Ordnance Survey and this dataset was post-processed using Leica Geo Office 8.3 software. Confirmation of heights was carried out by Mark Greaves, Geodetic Analyst of Ordnance Survey.

Note that small hand-held GPS receivers used for general navigation can only receive up to 12 GPS satellites and each at a single frequency and therefore these instruments have a poorer positional accuracy of ± 8 metres and a height accuracy of no better than $\pm 10\text{--}15$ metres. Some recently produced hand held GPS Garmin receivers can also receive signals from GLONASS satellites which greatly improve the speed at which these units can achieve a satellite “fix”.

The Leica NA730 level is routinely checked to make sure that the line of sight is correct when the instrument is set up horizontally; there is a standard surveying method to do this described in the users’ manual for these instruments. We also regularly check the functioning of the Leica Viva GS15 GNSS receiver against Statistical Quality Control (SQC) charts generated for a marked position. The chart associated with height measurement is shown below. The mean height above ODN (Ordnance Datum Newlyn) for a fixed point (measured on 20 different occasions for 30mins of data collection at each time) was calculated to be 136.392m. Further height measurements have been made on separate occasions over a period of 3 years using the same process parameters. The penultimate and last measurements were carried out before and after the surveys described in this report. The results shown on the graph are all within a range of \pm three SD (Standard Deviation), in this case one SD is $\pm 0.018\text{m}$ and the moving average is within 1SD. This demonstrates that our Leica Viva GS15 GNSS receiver is giving consistently precise results within the expected errors for the measurements (all points are within a range of 0.07m of one another).



In addition, we check the instrument periodically by taking measurements on an Ordnance Survey Fundamental Bench Mark, processing the data and comparing it with the OS derived values. Height should agree within about 0.02-0.03m.

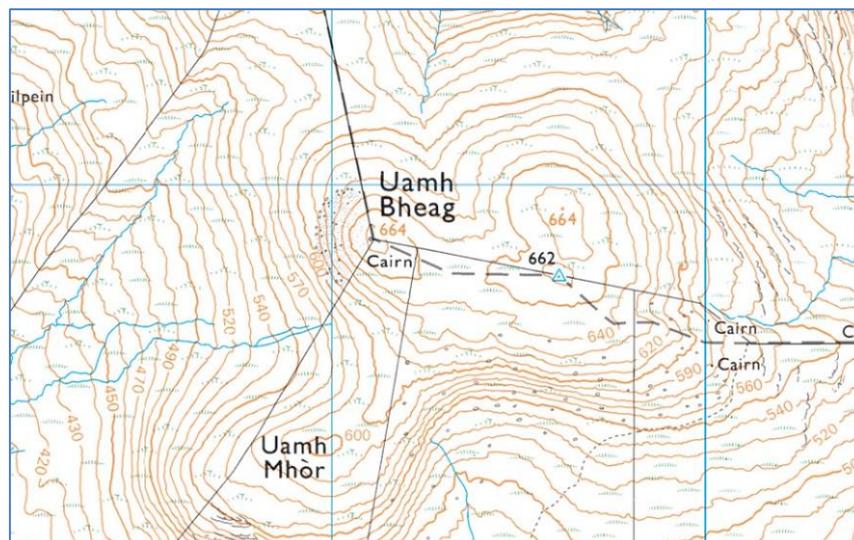
Checks were carried out on 13 October 2017 and 20 November 2017 at the Daresbury Fundamental Bench Mark and the results in the table below show excellent agreement between the Ordnance Survey measurement and our own.

Processing	Date	Height(m)
OS measurement		73.24
JB/GVJ GeoOffice 8.3	13-10-2017	73.23
JB/GVJ GeoOffice 8.3	20-11-2017	73.23

Conditions for the surveys, which took place between 12.00hrs and 16.35hrs BST on 25 October 2017, were poor. The temperature was about 8 degrees Celsius. The wind on the summits was moderate, blowing at just over 30 mph. The sky was overcast and the cloud-base was always beneath the summits, except for a few minutes during the morning. Later in the afternoon rain set in, but this did not impede the survey.

3) Character of the Hills

Uamh Bheag and its East Top are situated on the South side of Glen Artney, which itself lies just to the West of the village of Comrie. Access to Glen Artney is by a single track road that leaves the B827 near Cultybraggan Camp, just 1km South of Comrie. After 7.5km there is a car park which is situated just after a bridge over the Allt na Gaisge and from here the route to Uamh Bheag is through a farm gate just across the road. The farm track is left almost immediately and a SW route taken to the summit of the outlying top of Auchnashelloch Hill. From here a route South leads to a col where nearby there is a bridge across the Allt Ollach. The terrain just here is wet and boggy, but a line up Coire Fionnarachd soon leads to drier and easier ground beside the stream, which is now followed to the summit of Uamh Bheag. The view from the summit is extensive to the West, South and North, but the East Top obstructs the view in that direction. The summit of Uamh Bheag comprises a cairn constructed from large blocks of stone and adjacent to it is a meeting point of three fences.



An extract from the OS 1:25000 map (Ordnance Survey Crown Copyright) is shown above.

4) Survey of the Summit of Uamh Bheag

The first task for the survey team was to determine the position of the summit, although this was fairly obvious to the unaided eye as ground just on the far side of the fence from the cairn. The level

was set up at a convenient position and staff measurements were taken by the cairn and then around the immediate summit area which confirmed our initial assessment.

Staff reading by cairn = 0.515m

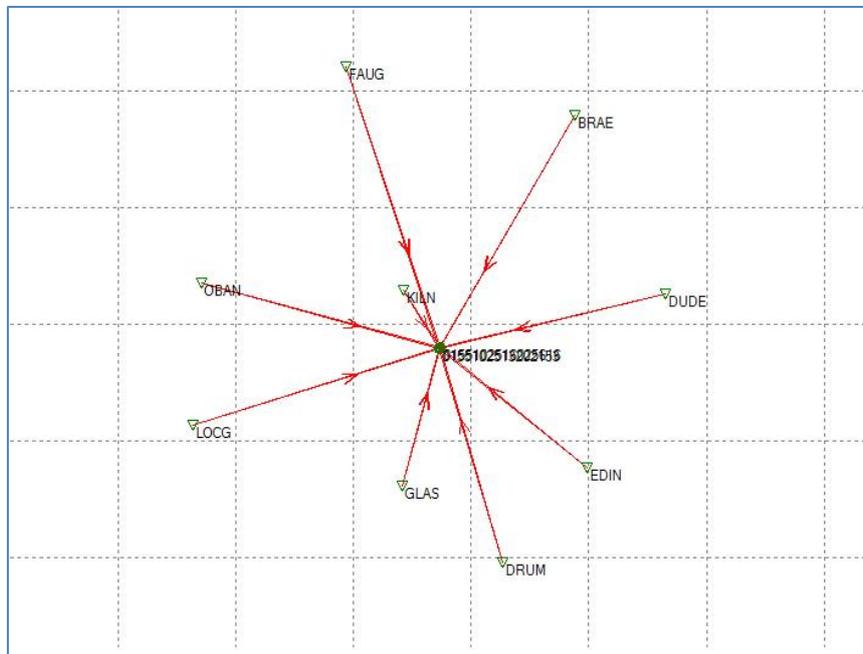
Staff reading on knoll near fence junction = 0.475m

Knoll is 0.04m higher than ground by cairn

The Leica Viva GS15 was set up over the summit using the short tripod configuration (see photo in Appendix 1). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.606m plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

4.1) **Results for the Summit of Uamh Bheag**

The data for the Leica Viva GS15 were processed in Leica GeoOffice 8.3 using the nine nearest base stations: (Killin – KILN 24km, Glasgow – GLAS 48km, Edinburgh – EDIN 64km, Drumalbin – DRUM 76km, Dundee - DUDE, 80km, Oban – OBAN 84km, Lochgilphead – LOCG 87km, Braemar – BRAE 93km and Fort Augustus – FAUG 102km). We used Broadcast Ephemeris data received by the GPS during the survey rather than Precise Ephemeris data, since we have found this makes little difference to the height results. The computed Tropospheric model was chosen for the calculations to suit the data collection times and the wide difference in height between the base stations and the summit of the mountain.



As far as is possible, the base stations are evenly distributed around the survey points and heights measured from each base station were within +/-0.06m of the mean result for the summit.

The results for Uamh Bheag are tabulated below:

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	269115.945	0.004	711853.204	0.001	665.771	0.010

5) Survey of the Summit of Uamh Bheag East Top

Having completed the survey of the summit of Uamh Bheag, we now moved onto the summit of Uamh Bheag East Top. The trig point is situated on a prominent knoll. North from here the ground drops steeply to an area of boggy ground before rising to a broad, flat, area of rough grass where there is a cairn, which may or may not be on its summit. Further North the ground drops slightly and then rises again to another broad, flat, featureless area. To the unaided eye any of these three summit areas could be the highest point of the East Top. On our first visit the summit area was in mist and had been for most of the day. This prevented work with the Leica NA730 level to determine the position of the summit.

Accordingly, the Leica Viva GS15 was set up using the short tripod configuration over the summit position that had been recorded by others (see photo in Appendix 2). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.661m plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

Ten figure grid references for this position acquired with hand-held GPS receivers are:

Garmin Oregon 450 NN 69609 11943* Accuracy: averaged Height = 669m

*grid reference converted to OSTN15

By the conclusion of data collection the weather had deteriorated further and consequently no work could take place to determine the true position of the summit on that day. An account of the subsequent level and staff survey which took place on 11 June 2018 describes that work (see Section 6).

5.1) Results for the Summit of Uamh Bheag East Top

The GNSS Data were processed as described in Section 4.1 using the same nearest Base Stations as for Uamh Bheag.

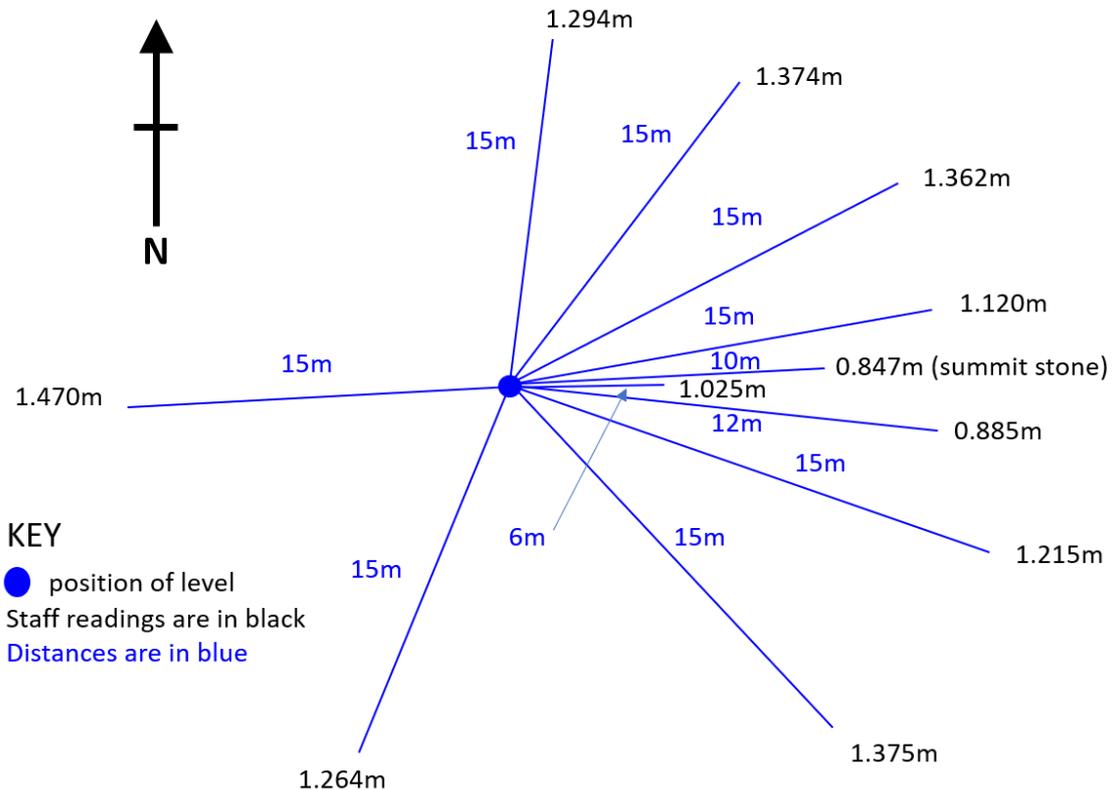
The results for Uamh Bheag East Top are tabulated below:

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	269607.668	0.002	711941.552	0.003	663.368	0.009

6) Level & Staff Survey of Summit Position on Uamh Bheag East Top

The first task for the survey team during the second visit was to determine whether or not the previously identified summit for Uamh Bheag East Top was correct. Poor visibility on the initial visit had prevented any measurement with level and staff. The stone placed at the prospective summit location was easily found and a hand-held GPS reading using a Satmap Active 20 at this spot (NN 69608 11942) agreed exactly with the previous reading taken with the Leica GS15. A Leica NA320 automatic level was set up about 15m West of the summit stone and readings were taken at various locations to assess for higher ground. At each location, surface vegetation was removed prior to staff placement. Readings taken are shown in the diagram below (distances and angles are approximate).

Confirmation of Summit Position of Uamh Bheag East top



No higher ground than that at the stone left during the previous visit could be found so this location is confirmed as the summit.

A line survey from the East Top summit to the nearby trig point was carried out to determine the height of the summit in relation to the flush bracket on the pillar. Survey data are shown in Appendix 3. The survey showed an average height difference for the East Top summit of 0.796m above the base of the trig point. The flush bracket was measured to be 0.266m above the base and the Ordnance Survey height for the trig point is 662.635m. Combining these figures gives a height difference between the flush bracket and the East Top of 0.529m and an absolute height for the East Top of 663.164m as determined from the OS flush bracket height.

The final part of the survey was to examine the low cairn to the south of the East Top and to determine whether or not it was situated at the highest point of a low rise between the East Top and the trig point. The line survey in a southerly direction had gone over this rise and showed that the cairn was approximately 110m from the East Top in a direction close to due South. The cairn was measured to be approximately 0.7m lower than the East Top. The NA320 level was set up about 15m to the north of the small cairn and several measurements were made of the ground around the cairn, using the same methodology as described above. Slightly higher ground to the NW of the cairn was found, the highest point being 18m (measured with the staff) NW of the cairn and 0.215m higher. Handheld GPS readings were taken at this position (NN 69635 11843) and at the cairn (NN 69645 11828) using a Satmap Active 20.

7) Summary of Operating Conditions

Variable	Uamh Bheag	Uamh Bheag East Top
Data collection summit (min)	122	121
Number of Base Stations used in Processing for all points	9	9
Epoch Time (sec)	15	15
Tropospheric Model	Computed	Computed
Geoid Model	OSGM15	OSGM15
Cut off Angle (deg)	15	15

8) Discussion of Results

The position of Uamh Bheag was clearly defined and on short grass. Consequently, we would estimate the height uncertainty associated with its correct locations to be +/-0.02m. The height uncertainty associated with a 2hr dataset has been measured by us and is +/-0.05m for data processed in propriety software. The measurement uncertainty for the height of Uamh Bheag is therefore $(0.02^2 + 0.05^2)^{0.5} = +/-0.05m$.

The position of Uamh Bheag East Top was much less clearly defined and situated in more vegetated terrain. Therefore we estimate the height uncertainty associated with locating that position accurately is +/-0.05m or better. A 2hr dataset was collected for this summit and, as above, this height uncertainty is also +/-0.05m. Therefore the overall uncertainty for the height of Uamh Bheag East Top is $(0.05^2 + 0.05^2)^{0.5} = +/-0.07m$

9) Coordinate Recovery Analysis

In order to verify the precision and consistency of a GNSS dataset, Ordnance Survey recommends a procedure called Coordinate Recovery Analysis. Instead of processing the data with reference to all the nearest OS Base Stations under approximately 100km distance, as used in this report, the data is first processed with reference to only the nearest Base Station. The data is then reprocessed with the survey point taken as a Reference Point and all the remaining Base stations taken as survey points. These measured values for the OS Base Stations can then be compared directly with the actual OS values for Position and Height. (This has been carried out via an Excel Spreadsheet supplied to us by OS).

Although the spreadsheet calculates a number of different parameters, two important ones are presented in the table below. “Height Difference **U** metres” is the vertical height difference between the height of the Base Station as measured in this survey compared with the actual OS value. “Separation **D_{ij}** metres” is the distance in 3-d space between the measured and actual OS values for each Base Station. The results for the survey are presented below.

Base Station	Code	Distance to Survey Point km.	Uamh Bheag		Uamh Bheag East Top	
			Height Difference U metres	Separation D_{ij} metres	Height Difference U metres	Separation D_{ij} metres
Killin	KILN	24				
Glasgow	GLAS	48	-0.021	0.030	-0.042	0.044
Edinburgh	EDIN	64	0.011	0.029	-0.029	0.037
Drumalbin	DRUM	76	-0.006	0.039	-0.032	0.034
Dundee	DUDE	80	0.090	0.092	0.031	0.036
Oban	OBAN	84	0.004	0.023	-0.049	0.054
Lochgilphead	LOCG	87	0.055	0.063	0.006	0.026
Braemar	BRAE	93	0.019	0.027	-0.015	0.017
Fort Augustus	FAUG	102	0.015	0.017	-0.002	0.005

All of the datasets have recovered terms of distance and height of the OS actual values, to below 0.1m which is considered acceptable by OS. In fact, apart from Dundee for the Uamh Bheag dataset at 0.092m, all of the other Base stations recovered to 0.06m or lower. Raw data are processed with base stations up to 100km from the survey point. Beyond this distance the models used to determine atmospheric corrections begin to break down because the atmosphere (in terms of pressure, temperature and composition) is less likely to be uniform over distances greater than this. (Of course 100km is somewhat arbitrary but has become generally accepted through surveying working practice). However, Coordinate Recovery uses distances greater than 100km to help probe the robustness of a GNSS dataset.

9) Ordnance Survey Verification

The results for this survey were submitted and have been validated on 09 July 2018 by Mark Greaves at Ordnance Survey. The Cartography Department have been informed and the heights from this survey will appear on new maps.

10) Summary of Heighting Results

Uamh Bheag was measured to be **665.8m \pm 0.05m** and the summit at Grid Reference *NN 69115 11853 is ground by the small cairn on the centre top.

Uamh Bheag East Top was measured to be **663.4m \pm 0.07m** and the summit at Grid Reference *NN 69607 11941 is on unfeatured ground.

Uamh Bheag is the higher hill and therefore qualifies as the Donald and Graham.

The results have been accepted by Ordnance Survey and forwarded to OS Cartography for relevant map changes.

*grid references are OSTN15

11) Acknowledgements

Many people contributed to the success of this survey.

We would especially like to thank the Scottish Mountaineering Trust for generously supporting the work and Rab Anderson and Andy Nisbet of the Scottish Mountaineering Club for their guidance and encouragement.

We also wish to thank Mark Greaves of the Ordnance Survey, who accepted the data and forwarded the results to OS Cartography for map changes. We also thank Mark for his support and advice that has helped us carry out our mountain heighting work over the past ten years.

John Barnard, Chris Crocker, Graham Jackson and Dave Marshall, 11 July 2018

Appendix 1
Uamh Bheag



Leica Viva GS15 collecting data on the summit of Uamh Bheag



Leica Viva GS15 collecting data on the summit of Uamh Bheag



Measuring the offset, 0.606m, for the Leica Viva GS15 on the summit of Uamh Bheag

Appendix 2

Uamh Bheag East Top



Measuring the offset, 0.661m, for the Leica Viva GS15 on Uamh Bheag East Top

Appendix 3

Title:- Uamh Bheag East Top

Instrument:- Leica NA720

Date:- 11-Jun-18

Point Number	Horizontal Line		Lower Stadia Line		Upper Stadia Line		Mean BS metres	Mean FS metres	Ht Difference metres	BS Distance metres	FS Distance metres
	Backsight R metres	Foresight F metres	Backsight R metres	Foresight F metres	Backsight R metres	Foresight F metres					
East Top to Trig Point base											
1	0.662	1.917	0.498	1.718	0.826	2.116	0.662	1.917		32.8	39.8
2	2.130	1.566	1.997	1.499	2.263	1.633	2.130	1.566		26.6	13.4
3	1.018	1.121	0.624	1.089	1.412	1.153	1.018	1.121		78.8	6.4
						Sum =	3.810	4.604	-0.794	138.2	59.6
Trig Point base to East Top											
1	0.747	1.800	0.708	1.465	0.786	2.130	0.747	1.798		7.8	66.5
2	2.060	1.862	1.880	1.714	2.240	2.010	2.060	1.862		36	29.6
3	2.211	0.562	2.061	0.452	2.361	0.672	2.211	0.562		30	22
						Sum =	5.018	4.222	0.797	73.8	118.1