

Surveys of Beinn na h-Uamha, Corra-bheinn and Cruachan Dearg

17 and 19 April 2016

The Teams:

Beinn na h-Uamha

Surveyors – John Barnard and Graham Jackson of G&J Surveys.

Guest surveyor – Laurence Rudkin

Corra-bheinn and Cruachan Dearg

Surveyors – John Barnard and Graham Jackson of G&J Surveys.

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. One such list is the Grahams, 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 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 Graham's list was not identical to the subset of Marilyn's 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 Graham's death Alan became the sole list author.

Alan Dawson has remeasured a number of hills within the original Graham's list using a Leica RX1250 GPS receiver. One of his conclusions is that of the two hills, Corra-bheinn and Cruachan Dearg which are both listed on OS maps with a height of 704m, Corra-bheinn is the higher summit and should only be listed in the Grahams. However, the surveys of these two hills have been carried out in a way that the Ordnance Survey is currently not prepared to accept. The OS is the national authority responsible for the maintenance of Britain's geographical features and both the SMT and SMC feel it is in the interest of the hillwalking community that the heights of hills are officially verified by Ordnance Survey for inclusion on their mapping for the benefit of all. These hills are given in the latest SMC Hillwalkers' Guide "The Grahams & The Donalds" but with a note in the text referring to the unratified survey. However, the SMC require that, the heights of hills have to be verified by Ordnance Survey to be accepted for their Guide Books and in these cases this verification has not been obtained.

Another list of interest to the SMT is The Corbetts, hills in Scotland between 2500 and 3000 feet with 500 feet of drop. Beinn na h-Uamha is currently in the list of Corbetts. However, with a map height of 762m, which is exactly 2500 feet, there is a strong possibility that this hill is below 2500 feet and therefore instead would qualify for the list of Grahams.

The aim of these surveys is to resolve this situation and obtain accurate heights for the summits of Beinn na h-Uamha, Corra-bheinn and Cruachan Dearg using a survey grade Leica Viva GS 15 Professional GNSS (Global Navigation Satellite System) receiver and submit the data sets collected to Ordnance Survey for verification. This will then lead to their heights being included on Ordnance Survey mapping and enable the SMC and others to provide the officially recognised heights in their future publications.

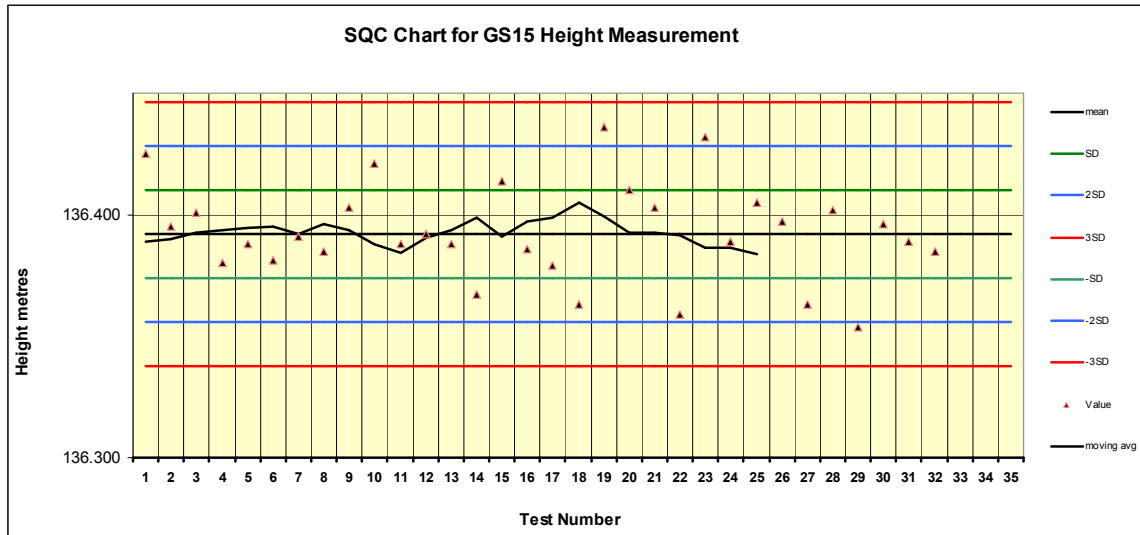
2) Equipment used and Conditions for Survey

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 $\pm 5\text{metres}$ and a height accuracy of no better than $\pm 10\text{metres}$. 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 18 months 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 29 March 2016 and 24 April 2016 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	29-03-2016	73.23
JB/GVJ GeoOffice 8.3	24-04-2016	73.23

Conditions for the survey of Beinn na h-Uamha which took place between 12.00hrs and 15.15hrs GMT on 17 April, were very poor. The temperature was about 2 degrees Celsius on the summit with a strong wind. At the start of the survey the wind speed was measured to be between 35 and 40mph but by the end of the survey it had increased to more than 50mph. Visibility was poor due to low cloud and we were frequently subjected to showers of sleet, snow and hail. These conditions limited the amount of surveying that could be carried out with level and staff but fortunately all the necessary measurements were made.

Conditions for the surveys of Corra-bheinn and Cruachan Dearg, which took place between 09.45hrs and 15.30hrs GMT on 19 April were much better. At the start the weather was cool, 5 degrees Celsius, but visibility was good despite the hazy sunshine. However, during the day the temperature rose and the sky cleared to leave the hills bathed in sunshine. The wind speed was low and was measured to be between 5 and 10mph.

3) Character of the Hills

Beinn na h-Uamha (Hill Number 1358, Hill Section 18B, OS 1:50000 Map 40, OS 1:25000 Map 391, Grid Ref NM917664) lies on the North side of Glen Gour about 7km North West of Sallachan. This hill can be approached from the West via Strontian Glen when Sgurr a'Chaorainn can also be

climbed. However, the easier approach to Beinn na h-Uamha, if this hill is to be climbed on its own, is via Glen Gour. There is a small parking area on the road by the bridge at Sallachan and a track leads up Glen Gour on the southern side of the River Gour. After about 4km it is possible to ford the River Gour and then follow the East ridge to the summit of Beinn na h-Uamha. This is a rough route and is quite steep in places but it is possible to weave around the various rocky obstacles to find a route to the summit. The summit appears to be the cairn. The adjoining hills are rocky and remote, and the views from the summit are extensive when they can be seen, but not during this survey!

Corra-bheinn (Hill Number 1306, Hill Section 17E, OS 1:50000 Map 48, OS 1:25000 Maps 375E and 375W, Grid Ref NM573321) and Cruachan Dearg (Hill Number 1307, Hill Section 17E, OS 1:50000 Map 48, OS 1:25000 Maps 375E and 375W, Grid Ref NM568332) lie about 1.1km apart in the NE area of the Island of Mull. The highest hill in Mull, the Munro Ben More, lies about 4km to the West of Cruachan Dearg and is adjoined to it by a ridge that runs over the distinctive “nose” of A’Chioch. Both Corra-bheinn and Cruachan Dearg have rocky and steep flanks on their Southern sides. Although there is only 130m of drop between them, the ground in places is very steep making the traverse of the two hills more difficult than one might expect.

The shortest approach to the hills is from the South. Limited parking can be found on the verge of the A849 near Teanga Brideig. From here the direct ascent up the steep grassy slopes of Corra-bheinn can be made. This is hard going and towards the upper slopes the ground in places becomes steeper. However after a number of rocky and scree outcrops are passed, the going becomes a little easier up to the summit area. Cruachan Dearg is very similar in nature, and once the traverse to it from Corra-bheinn has been made, a descent can be made by continuing at first North West and then West down the West ridge to meet the stalkers path at the bealach Creag Mhic Fhionnlaidh. Both these hills are excellent summits and are fine examples of rugged hills that are characteristic of the Western Isles.

4) Survey of Beinn na h-Uamha

The first task for the survey was to try to identify the highest point using the Leica NA730 automatic level and staff. We were able to identify as the highest point a rock within the edge of the cairn that did not appear to be part of it. It was not physically possible to set up the Leica GS15 on its tripod over this point and because of the strong wind we set it up over a convenient rock on the sheltered east side of the cairn. A photograph of the Leica GS15 set up with the Short Tripod Configuration over this point is shown in Appendix 1.

Staff readings for these positions were:-

“Summit” rock in edge of cairn = 0.065m

GS15 set up position = 0.271m

Therefore height to add GS15 data is $0.271 - 0.065 = 0.206\text{m}$

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 0.386m (see photograph in Appendix) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

While GNSS Data was being collected we decided to dismantle the cairn in order to check that we were not missing any higher ground. We found that the cairn was indeed built over solid rock and that this point was higher than the point we had identified previously on the edge of the cairn. Once the 2hours of GNSS Data had been collected, the Leica NA730 level was set up again on the tripod so that staff measurements could be taken from the survey point, the highest rock within the cairn and the rock at the edge of the cairn. The staff readings were:-

GS15 set up position = 0.857m

Rock at edge of Cairn = 0.643m

Summit rock under cairn = 0.453m

The rock underneath the cairn was 0.190m higher than the rock at the edge of the cairn.

The height of the summit was $0.857 - 0.453 = 0.404\text{m}$ higher than the GS15 set up position.

4.1) Results for Beinn na h-Uamha

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the seven nearest base stations: (Oban– OBAN 32km, Arisaig – ARIS 32km, Fort Augustus - FAUG 63km, Killin – KILN 75km, Lochcarron – LCAR 76km, Lochgilphead - LOCG 81km and Tiree – TIRE 94km). 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. Since the GS15 was not set up directly over the summit position a height correction is needed. The total vertical offset used was 0.255m (standard for short tripod assembly) plus 0.386, for the height above the survey point as measured by the tape minus 0.404m for the difference in height between the summit and the survey point. This gives a total vertical offset of $0.386 + 0.255 - 0.404 = 0.237\text{m}$ which was used within the GeoOffice 8.3 processing parameters.

As far as is possible, the base stations are evenly distributed around the survey point and heights measured from each base station were within +/-0.03m of the mean result for summit of Beinn na h-Uamha.

The results for Beinn na h-Uamha are tabulated below:

Processing	Feature	Easting	Northing	Height(m)
Leica GeoOffice 8.3	Rock under cairn	191715.458	766423.263	762.375

The height of Beinn na h-Uamha is 762.38m

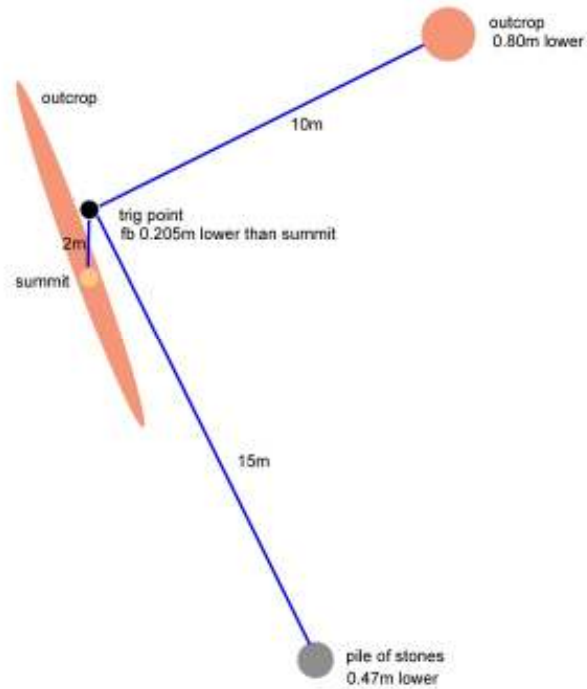
The data for the summit of Beinn na h-Uamha recorded by hand-held Garmin GNSS receivers was:-

Garmin Oregon 450	NM 91718 66415	Accuracy: averaged	Height = 767m
Garmin Montana 600	NM 91720 66413	Accuracy: averaged	Height = 761m
Garmin Etrex 20	NM 91718 66415	Accuracy: averaged	Height = 764m

5) Surveys of Corra-bheinn and Cruachan Dearg

Corra-bheinn

A diagram of the summit area of Corra-bheinn is shown below (North to top). Also a photograph of this area with the Leica GS15 set up over the summit position is shown in Appendix 2.



About 2m South of the Trig Point there is a rocky rib which looks to be the highest point. This was confirmed with staff readings taken with the Leica NA730 automatic level set up adjacent to the trig point. About 10m NE of the trig point there is a rock outcrop which staff measurements showed to be 0.8m lower than the hill's summit. About 15m SE of the trig point is a pile of stones that may have been a dismantled cairn but that was measured to be 0.47m lower than the highest point. A staff reading was also taken to the Flush Bracket on the trig point to check our measurements against the OS trig point database.

The staff readings that were taken were:-

Trig point Flush Bracket = 0.479m

Summit rock = 0.274m

Pile of stones 15m SE of trig point = 0.740m

Outcrop 10m NE of trig point = 1.071m

Next the tripod was set-up over the summit position and the Leica Viva GS15 was then fixed to it with a clamp and tribrach (the "short tripod" configuration). 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 0.299m (see photograph in Appendix 2) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

Cruachan Dearg

The cairn is the obvious highest point on Cruachan Dearg. However the Leica NA730 automatic level was set up on a tripod adjacent to the cairn and staff readings were systematically taken around it. It appeared as though the cairn was built over a rock outcrop which was visible on the SE side of the cairn. The cairn was then partially dismantled to check this outcrop but staff measurements showed it to be dropping towards the centre of the cairn.

It was not possible to set up directly over the exact summit position. Therefore the tripod was set-up as close as possible to it and the Leica Viva GS15 was then fixed to it with a clamp and tribrach (the “short tripod” configuration). A small platform of rocks was constructed directly under the GS15 with this platform levelled to the summit position (see photograph in Appendix 3). 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 0.451m (see photograph in Appendix 3) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

5.1) Results for Corra-bheinn and Cruachan Dearg

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the five nearest base stations: (Oban– OBAN 31km, Lochgilphead – LOCG 55km, Arisaig - ARIS 55km, Tiree – TIRE 59km and Killin – KILN 100km). Since Corra-bheinn and Cruachan Dearg are about 1km distance from each other the same pattern of Base stations is relevant to each hill. Unfortunately no signal from Tiree Base station was available for the Cruachan Dearg survey and so this limited the number of Base stations to just four. 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 +/-0.07m of the mean result for summits of Corra-bheinn and Cruachan Dearg.

The results for Corra-bheinn and Cruachan Dearg are tabulated below:

Hill	Feature	Easting	Northing	Height(m)
Corra bheinn	Rock outcrop	157329.797	732185.645	704.943
Cruachan Dearg	Rock under cairn	156840.951	733200.612	704.078

The data for the summit of Corra-bheinn recorded by hand-held Garmin GNSS receivers was:-

Garmin Montana 600	NM 57336 32178	Accuracy: averaged	Height = 707m
Garmin Etrex 20	NM 57335 32179	Accuracy: averaged	Height = 710m

The data for the trig point on Corra-bheinn recorded by hand-held Garmin GNSS receivers was:-

Garmin Oregon 450	NM 57334 32180	Accuracy: averaged	Height = 708m
Garmin Montana 600	NM 57335 32179	Accuracy: averaged	Height = 707m
Garmin Etrex 20	NM 57335 32177	Accuracy: averaged	Height = 708m

The data for the summit of Cruachan Dearg recorded by hand-held Garmin GNSS receivers was:-

Garmin Oregon 450	NM 56847 33193	Accuracy: averaged	Height = 710m
Garmin Montana 600	NM 56848 33193	Accuracy: averaged	Height = 706m

The heights of Corra-bheinn and Cruachan Dearg are 704.94m and 704.08m respectively

6) Summary of Operating Conditions

Variable	GS15 on Beinn na h-Uamha	GS15 on Corra-bheinn	GS15 on Cruachan Dearg
Data collection summit (min)	121	122	123
Number of Base Stations used in Processing for all points	7	5	4
Epoch Time (sec)	15	15	15
Tropospheric Model	Computed	Computed	Computed
Cut off Angle (degs)	15	15	15

7) Discussion of Results

All the summit positions for the three hills measured in these surveys were on rock and consequently the height uncertainty associated with locating these positions was estimated to be no more than +/-0.01m. The height uncertainty associated with the GNSS measurement from a 2hr dataset has been measured by us and is +/-0.05m for data processed in propriety software. The measurement uncertainty for the heights of each summit is therefore: $(0.05^2 + 0.01^2)^{0.5} = 0.05\text{m}$.

The Ordnance Survey Database gives the height of the Flush Bracket on the trig point of Corra-bheinn to be 704.697m. Using level and staff we measured the height of the Flush Bracket to be $0.479 - 0.274 = 0.205\text{m}$ LOWER than the hill's summit. Therefore our measurement for the height of the Flush Bracket is $704.943 - 0.205 = 704.738\text{m}$. The difference between the two measurements is 0.04m and well within the expected measurement uncertainty.

As stated in the Introduction to this report, Alan Dawson had already surveyed Corra-bheinn and Cruachan Dearg using his Leica RX 1250 GPS receiver. Although Alan did not use a level and staff to identify the highest points, the summit coordinates that he obtained for Corra-bheinn are 0.1m distant from those measured in this survey. However Alan's coordinates for Cruachan Dearg are 1.52m distant and in a direction 57 degrees West of North from our identified summit. Although not significant, Alan recorded the height of Cruachan Dearg to be 0.03m lower. His summit position is basically on the opposite side of the summit cairn from the position we had identified and the height difference is in accord with staff measurements we had taken around the cairn.

8) Coordinate Recovery Analysis

In order to verify the accuracy 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 tables 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 three surveys are presented below.

Beinn na h-Uamha:-

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D_{ij} metres
Oban	OBAN	32		
Arisaig	ARIS	32	-0.033	0.046
Fort Augustus	FAUG	63	-0.032	0.037
Killin	KILN	75	-0.040	0.053
Lochcarron	LCAR	76	-0.049	0.053
Lochgilphead	LOCG	81	-0.011	0.016
Tiree	TIRE	94	-0.010	0.015
Inverness	INVR	111	-0.011	0.037
Glasgow	GLAS	121	-0.028	0.036
Braemar	BRAE	127	-0.016	0.036

Corra-bheinn:-

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D_{ij} metres
Oban	OBAN	31		
Lochgilphead	LOCG	55	0.006	0.013
Arisaig	ARIS	55	-0.013	0.031
Tiree	TIRE	59	-0.006	0.016
Killin	KILN	100	-0.020	0.030
Fort Augustus	FAUG	111	-0.029	0.034
Campbletown	CAML	113	0.064	0.065
Barra	BARR	113	-0.041	0.044
Lochcarron	LCAR	115	-0.010	0.028
Glasgow	GLAS	120	-0.026	0.029

Cruachan Dearg:-

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D_{ij} metres
Oban	OBAN	32		
Lochgilphead	LOCG	54	-0.023	0.040
Arisaig	ARIS	56	0.007	0.013
*Tiree	TIRE	57	N/A	N/A
Killin	KILN	101	-0.010	0.032
Fort Augustus	FAUG	111	-0.024	0.033
Barra	BARR	111	-0.053	0.054
Campbletown	CAML	114	-0.070	0.070
Lochcarron	LCAR	115	-0.030	0.044
Glasgow	GLAS	121	-0.005	0.020

* No Base station data was available for this survey.

The results for Beinn na h-Uamha, Corra-bheinn and Cruachan Dearg show consistent datasets as all measured OS Base stations are within 0.07m distance and height of the OS actual values.

10) Ordnance Survey Verification

The results for these surveys were submitted for validation to Mark Greaves at Ordnance Survey. The height for Beinn na h-Uamha was accepted since there is no change to the map height. The new height of 704.9m for Corra-bheinn has also been accepted and 705m will appear on subsequent Ordnance Survey maps. The height of Cruachan Dearg will remain as 704m and therefore the OS maps will differentiate between these previous twin summits.

11) Summary of Heighting Results

Beinn na h-Uamha was measured to be **762.4 \pm 0.05m**, the summit is rock beneath the cairn at NM 91719 66415*. The Corbett classification for Beinn na h-Uamha should be retained by the SMC.

Corra-bheinn was measured to be **704.9 \pm 0.05m**, the summit being a rock outcrop at NM 57336 32179*.

Cruachan Dearg was measured to be **704.1 \pm 0.05m**, the summit being a rock beneath the cairn at NM 56848 33193*.

Corra-bheinn is 0.86m higher than Cruachan Dearg and therefore qualifies for Alan Dawson's list of Grahams.

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

*grid references for use with Garmin hand-held receivers

12) Acknowledgements

Many people contributed to the success of these two surveys.

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 seven years.

John Barnard, Graham Jackson and Laurence Rudkin, 05 May 2016

Appendix 1 - Beinn na h-Uamha



Leica Viva GS 15 collecting GNSS Data over Rock next to Summit Cairn



Cairn dismantled showing rock outcrop hidden below it



Measuring the offset for the Leica Viva GS15 on Beinn na h-Uamha



Beinn na h-Uamha from Glen Gour

Appendix 2 – Corra-bheinn



Leica GS15 Collecting data on the Summit of Corra-bheinn from Same Viewpoint as in Diagram on Page 5



Measuring the offset for the Leica Viva GS15 on the summit of Corra-bheinn

Appendix 3 – Cruachan Dearg



Leica GS15 setup to highest point within the Cairn



Measuring the offset for the Leica Viva GS15 on the summit of Cruachan Dearg