# Survey of Ben Aslak

**23 September 2016**

**The Team:**

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 Marilyns termed the Elsies 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.

The aim of this survey was to obtain an accurate height for the summit using a survey grade Leica Viva GS 15 Professional GNSS (Global Navigation Satellite System) receiver and report this to the SMC.

## 2) Equipment used and Conditions for Survey

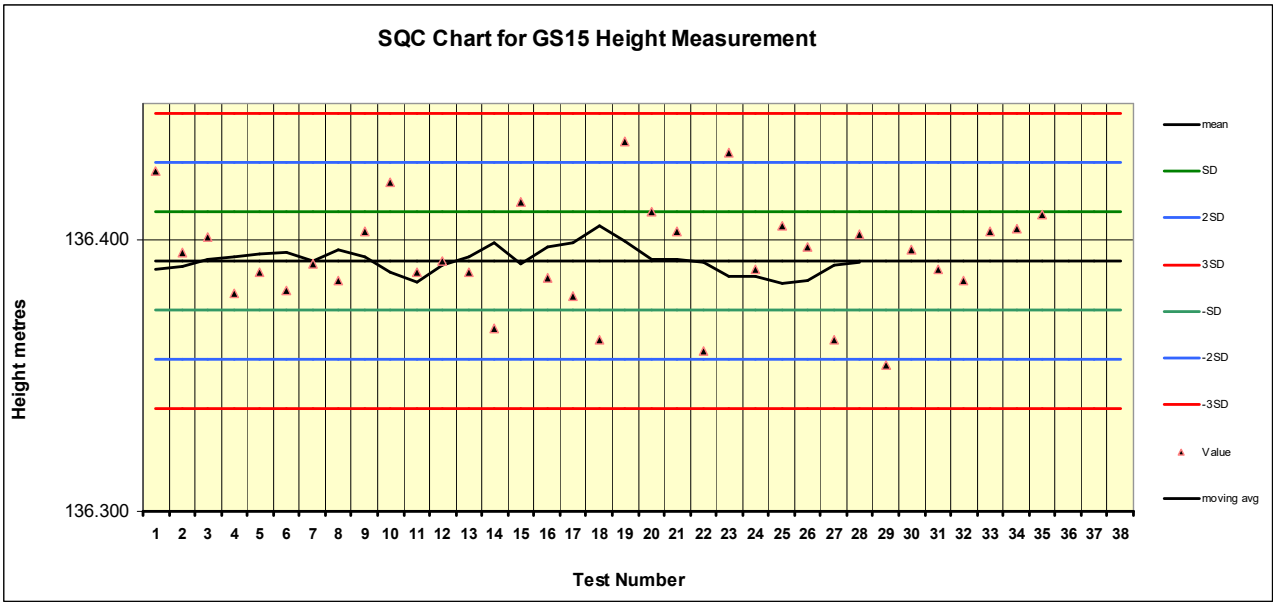
The summit position was identified using a Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" **E**-staff extendable to 5m as required by Ordnance Survey.

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 (+/- 0.01m) and heights (+/-0.05m), 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 +/-5metres and a height accuracy of no better than +/-10 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 +/- three SD (Standard Deviation), in this case one SD is +/-0.018m 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 17 May 2016 and 27 September 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.

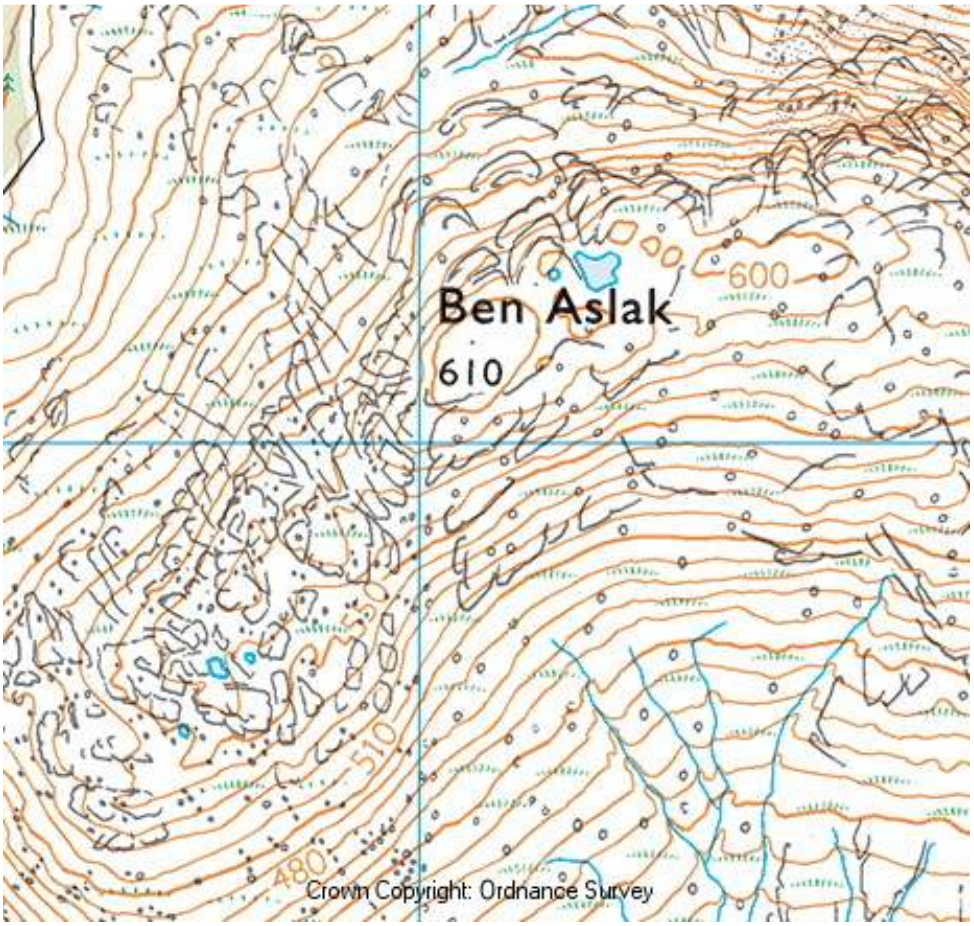
| Processing | Date | Height(m) |
|---|---|---|
| OS measurement | | 73.24 |
| JB/GVJ GeoOffice 8.3 | 17-05-2016 | 73.22 |
| JB/GVJ GeoOffice 8.3 | 27-09-2016 | 73.24 |

Conditions for the survey of Ben Aslak which took place between 10.45hrs and 16.30hrs BST on 23 September 2016 were good. The temperature was about 10 degrees Celsius. The wind on the summit was blowing between 20 and 30mph with gusts up to 35mph. Generally visibility was good and improved during the day, but at the beginning of the survey mist was swirling over the summit. The weather conditions did not impede the survey.

## 3) Character of the Hill

Ben Aslak (Hill Number 1283, Hill Section 17C, OS 1:50000 Map 33, OS 1:25000 Maps 412, 413N, Grid Ref NG750191) lies in the East Corner of the Isle of Skye and is one of three hills that dominate the view West to Skye from the mainland at Glenelg. A small car ferry runs from Glenelg to Kylerhea and the minor road from there that leads into Skye bisects Ben Aslak from the other two hills at Bealach Udal. The ferry only runs in the summer months and has gained a reputation for views of the White-tailed Eagles that nest in this area. Ben Aslak can easily be climbed on its own from Bealach Udal where there are limited spaces for off-road parking. The track to the mast can be used to start the ascent but little of the ascent is gained by it. From the mast, the ascent continues up grass aiming for the bealach between the minor top Beinn Bheag and Ben Aslak and then in a South East direction to reach a lochan at about 600m height. From there one turns South West over rougher ground to soon reach the summit of Ben Aslak

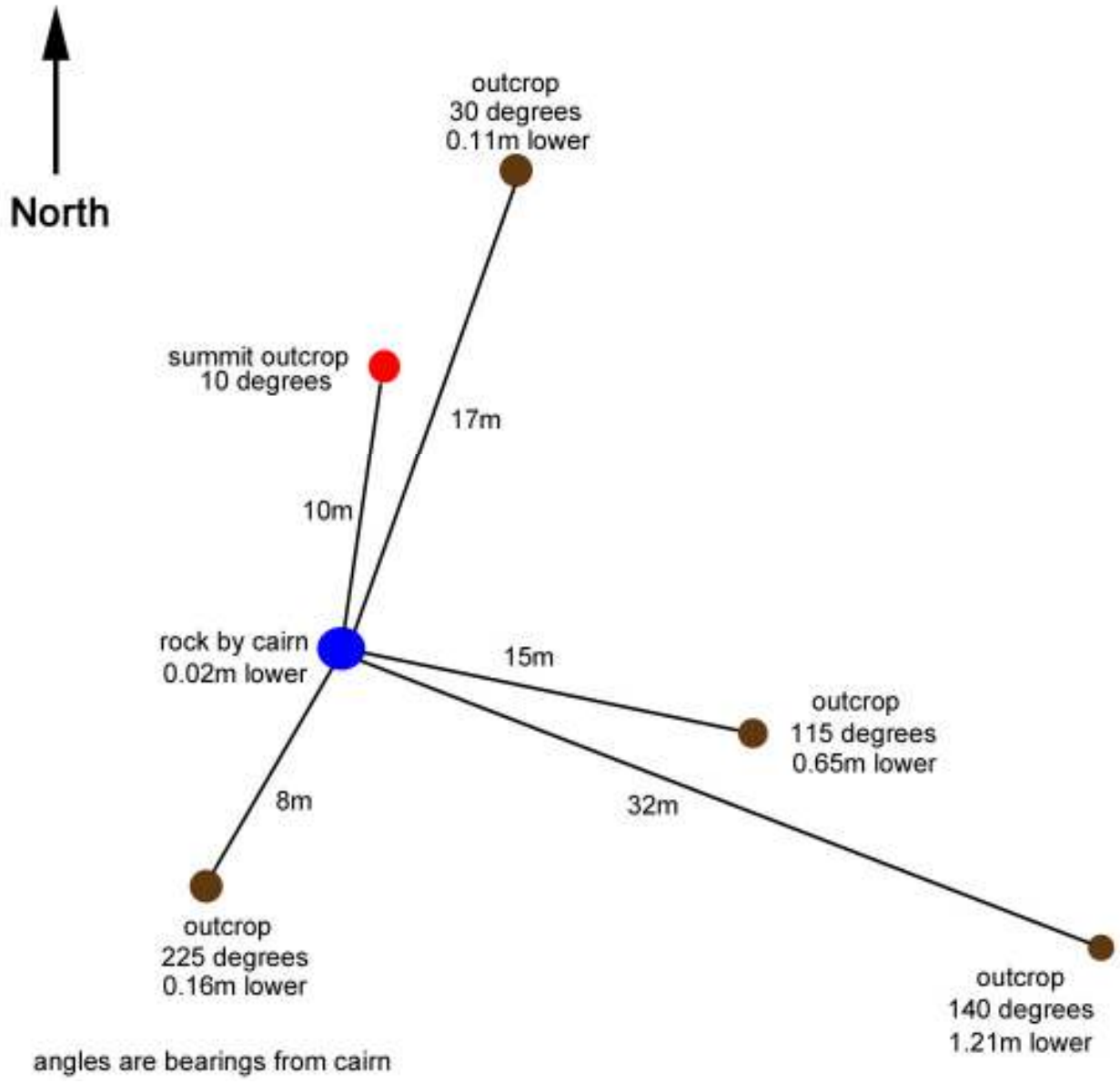
An extract from the OS 1:25000 map is shown below.




## 4) Survey of the Summit of Ben Aslak

The first task for the survey was to try to identify the position of the summit which was not visually obvious. The Leica NA730 automatic level was set up at a convenient position so that all possible summit candidates could be measured. Having dismantled the cairn to check for higher ground underneath it, staff readings were taken from all summit candidate positions. A schematic diagram of the summit area is shown below.

## Schematic Diagram of Summit Area




The summit position was identified as a rock outcrop 10m distant from the cairn and at a bearing of 10 degrees from it. The highest rock under the cairn was 0.02m lower. All other candidates were measured to be greater than 0.1m lower.

The East Top, about 300m distant, was also observed and photographed through the Leica NA730 level in order to determine the approximate height difference between it and the summit on the West Top.

The Leica Viva GS15 was set up over the summit using the short tripod configuration (see photo in Appendix). 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 0.404m 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 Ben Aslak Summit

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the six nearest base stations: (Lochcarron – LCAR 29km, Arisaig – ARIS 34km, Fort Augustus – FAUG 63km, Ullapool - ULLO 85km, Oban – OBAN 86km and Inverness – INVR 96km). 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 +/-0.02m of the mean results for the summit.

The results for Ben Aslak are tabulated below:

| System | Easting | error(1SD) | Northing | error(1SD) | Height(m) | error(1SD) |
|---|---|---|---|---|---|---|
| GS15 | 175075.249 | 0.002 | 819132.875 | 0.003 | 608.983 | 0.004 |

The data for the summit on Ben Aslak recorded by hand-held Garmin GNSS receivers were:-

| | | | |
|---|---|---|---|
| Garmin Oregon 450 | NG 75079 19123 | Accuracy: averaged | Height = 615m |
| Garmin Montana 600 | NG 75080 19121 | Accuracy: averaged | Height = 610m |
| Garmin Etrex 20 | NG 75080 19122 | Accuracy: averaged | Height = 612m |

### 4.2) Results for Ben Aslak East top

The photograph of the East Top taken through the Leica NA730 level is shown in Appendix 1. This shows the cairn and above it the centre line (the long line at the top of the photograph) and the lower stadia line (the short line).

The distance between the position of the level and the East Top was determined from the 1:10k map and found to be 420m. The vertical difference between the centre line and the lower stadia line is 1/200 of the horizontal distance, which is 2.1m. The difference between the centre line and the ground by the cairn is 1.68 times this, ie (1.68 x 2.1) or 3.5m. Now the level was 0.3m above the summit position on the West Top. Therefore the East Top is 3.5 - 0.3 = 3.2m lower than the West Top.

The cairn in the photograph is about 0.9m high.

## 5) Summary of Operating Conditions

| Variable | GS15 on Summit |
|---|---|
| Data collection summit (min) | 123 |
| Number of Base Stations used in Processing for all points | 6 |

| | |
|---|---|
| Epoch Time (sec) | 15 |
| Tropospheric Model | Computed |
| Geoid Model | OSGM36(15) |
| Cut off Angle (degs) | 15 |

## 6) Discussion of Results

Since the position of the summit was clearly defined, we would estimate a height uncertainty associated with its correct location of +/-0.01m. 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 the summit is therefore $(0.01^2 + 0.05^2)^{0.5} = 0.05$m.

The measurement uncertainty of the photographic measurement of the East Top is about +/-0.2m assuming that the highest natural ground has been identified in the photograph and that there is no hidden higher ground under the cairn.

## 7) 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 $\mathbf{D_{ij}}$ 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.

**Ben Aslak summit:-**

| Base Station | Code | Distance to Survey Point km. | Height Difference **U** metres | Separation $\mathbf{D_{ij}}$ metres |
|---|---|---|---|---|
| Lochcarron | LCAR | 29 | | |
| Arisaig | ARIS | 34 | -0.007 | 0.009 |
| Fort Augustus | FAUG | 63 | 0.019 | 0.019 |
| Ullapool | ULLO | 85 | 0.006 | 0.010 |
| Oban | OBAN | 86 | 0.003 | 0.016 |
| Inverness | INVR | 96 | 0.009 | 0.011 |

| | | | | |
|---|---|---|---|---|
| Benbecula | BENB | 103 | -0.044 | 0.045 |
| Tiree | TIRE | 106 | -0.013 | 0.022 |
| Barra | BARR | 111 | -0.035 | 0.036 |
| Stornoway | STOR | 118 | -0.013 | 0.017 |

All of the datasets have recovered to 0.05m or better in terms of distance and height of the OS actual values, well below 0.1m which is considered acceptable by OS. 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. The base stations BENB, TIRE, BARR and STOR were not used in the calculation of the heights of the summit.

Even a 2hr GNSS dataset can sometimes produce anomalies. Nevertheless, it emphasises the importance of long collection times for maximising accuracy and consistency for position and height determinations.

## 8) Ordnance Survey Verification

The results for this survey were submitted for validation to Mark Greaves at Ordnance Survey. The height for Ben Aslak was accepted and spot height for the summit on OS Maps will be changed from 610m to 609m.

## 9) Summary of Heighting Results

**Ben Aslak** was measured to be **609.0m+/-0.05m** and the summit is a rocky outcrop 10m and on a bearing of 10 degrees from the cairn.

As the height of Ben Aslak is below 609.60m, it has insufficient height to qualify for the 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

## 10) 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 seven years.

John Barnard and Graham Jackson, 13 October 2016

# Appendix 1 – Ben Aslak Summit

**Leica GS15 Collecting Data on the Summit 10m from Cairn**


**Measuring the offset, 0.404m, for the Leica Viva GS15 on the summit**


**Cairn with the two SE outcrops in the Background**


**Summit Position and NE Outcrop**


**Cairn with SW Outcrop Behind**


**Leica GS15 on Summit with East Top in Background**

**East Top as Seen Through the Level**