

Survey of Little Wyvis

25 March 2017

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 Corbetts, mountains in Scotland of height between 2500 feet (762.0 metres) and 3000 feet (914.4 metres) but with 500 feet (152.4 metres) or more of drop. This list was compiled by J Rooke Corbett but was not published until after his death in 1949. J Rooke Corbett's sister passed on the list to the SMC, who after the initial publication, have made several revisions as new data on these hills became available.

The height of Little Wyvis on current OS 1:50000 and 1:25000 maps is listed as 764m and 763m respectively. Since photogrammetric measurements have an uncertainty in height of +/-3m, there is a possibility that Little Wyvis does not exceed 2500 feet and therefore should not be included in the list of Corbetts. The aim of this survey was the determination of an accurate height for the summit of Little Wyvis using a survey grade Leica Viva GS 15 Professional GNSS (Global Navigation Satellite System) receiver and the submission of the data sets collected to Ordnance Survey for verification. This will then lead to the result being confirmed on Ordnance Survey mapping and enable the SMC and others to provide the officially recognised height in their future publications.

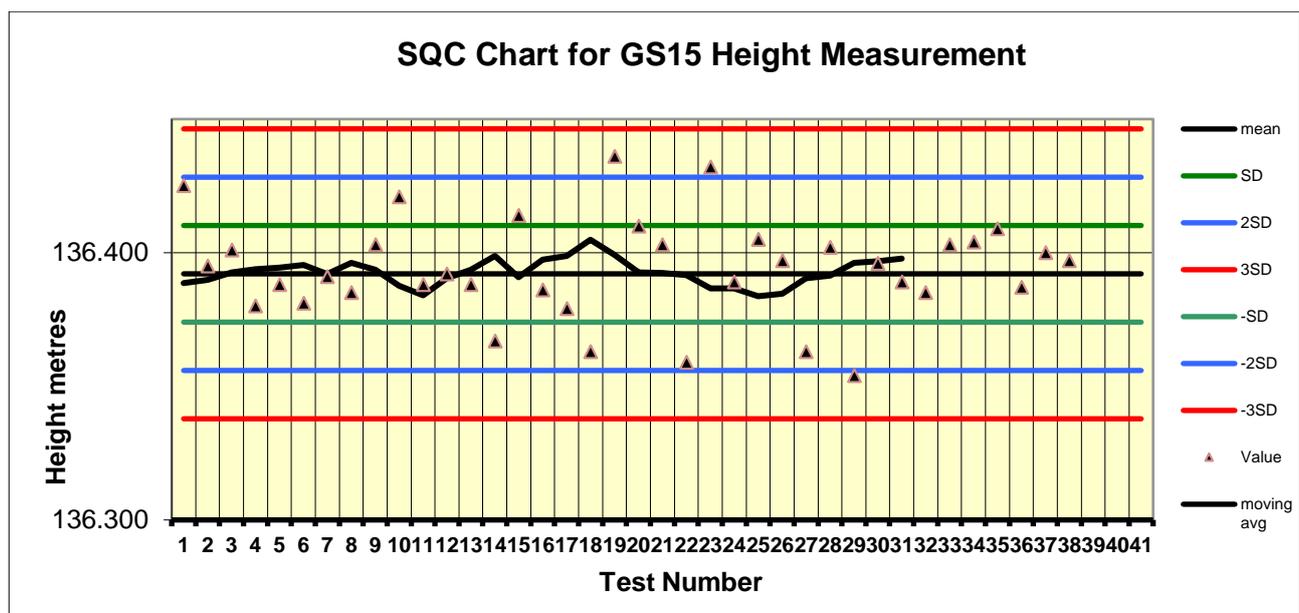
2) Equipment used and Conditions for Survey

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.

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 18 months using the same process parameters. The last and penultimate measurements were carried out after and before the mountain survey 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 27 September 2016 and 04 April 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	27-09-2016	73.24
JB/GVJ GeoOffice 8.3	04-04-2017	73.23

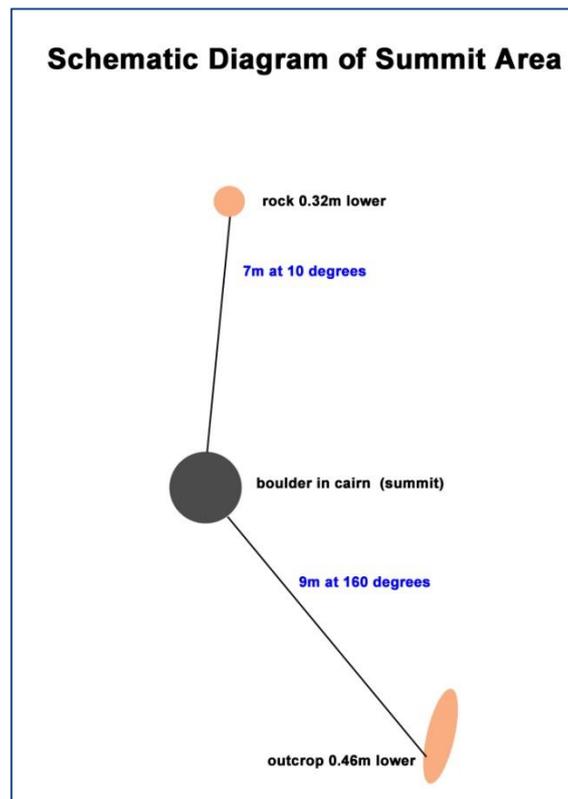
Conditions for the survey of Little Wyvis, which took place between 12.45hr and 15.30hr GMT on 25 March, were good. The temperature on the summit was 8 degrees Celsius, but a wind speed of 30mph gave significant wind-chill. The summit was in sunshine all day, as was its higher neighbour Ben Wyvis and consequently visibility was excellent.

3) Character of the Hill

Little Wyvis (Hill Number 1097, Hill Section 15B, OS 1:50000 Map 20, OS 1:25000 Map 437S, Grid Ref NH429644) lies about 5km NE of Garve off the A835 Ullapool to Inverness road. The map shows a network of tracks on the West side of the hill that leads eventually to the summit. However, this area has been used for a deer-rearing programme and historically walkers have been discouraged from using these tracks. Just over 3km further North along the road, however, there is a track that follows the North bank of the Allt a' Bhealaich Mhoir to the edge of the extensive forestry which covers this area. This is the walkers' route to Ben Wyvis and since one of the authors last used it in 1993, it has been transformed from a muddy track over peat hags to a well-engineered path that leads out of the forestry and up An Cabar. The original small car park has been re-sited about 200m South along the road and enlarged considerably in the process. This makes an excellent starting point for the ascent of Little Wyvis and the new path provides a fast route out of the forestry. Once the forest edge is reached the path is left and the stream, which by this time is relatively narrow, is crossed and the now pathless ascent of Little Wyvis begins. From the stream up to 600m the terrain is boggy and heathery, which slows progress relative to the fast ascent up the path. However, at about 650m a track is crossed on the short walk to the ridge and from here the vegetation changes from heather to grass and the going eases. The summit is adorned by a large cairn and the view from here is extensive. To the SE the Cromarty Firth with several attendant oil platforms is clearly seen and beyond the Moray Firth is also visible. To the West and in the distance lie the Fannichs, Beinn Eighe and Liathach, but to the North the view is dominated by An Cabar and the massif of Ben Wyvis.

4) Survey of Little Wyvis

A diagram of the summit area is shown below.



The first task for the survey was to identify the highest point using the Leica NA730 automatic level and staff. As a starting point the large untidy cairn was investigated to see if it hid high ground. After dismantling a large proportion of the cairn we found a large embedded boulder. This boulder

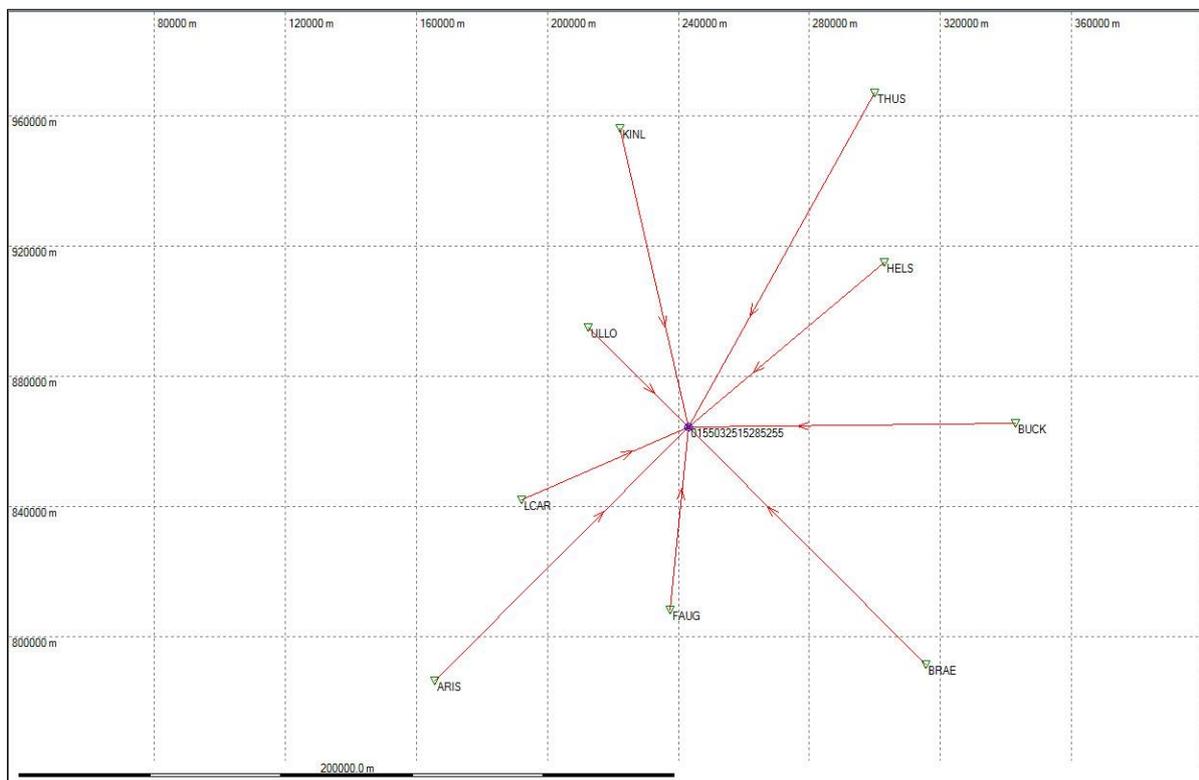
protruded 20 – 30cm above ground level. Next, two rocks in the vicinity of the cairn were identified as possible summit positions. Finally, the level was set up in a convenient position near the cairn and staff readings were taken on each of these features. The highest point was the embedded boulder in the cairn.

Next, the tripod was set-up over the embedded boulder in the cairn 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 0.460m (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. Once data collection was completed the Leica Viva GS15 was dismantled and the cairn was carefully rebuilt.

4.1) Results for Little Wyvis

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the nine nearest base stations: (Ullapool– ULLO 43km, Loch Carron – LCAR 55km, Fort Augustus - FAUG 56km, Helmsdale – HELS 80km, Kinlochbervie – KINL 94km, Buckie - BUCK 101km, Braemar – BRAE 103km, Arisaig – ARIS 109km and Thurso– THUS 118km). Normally we use base stations up to 100km distant, but in this case only five fulfilled this criterion and consequently it was decided to increase the range to 120km. We used Broadcast Ephemeris data received by the GNSS receiver 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.

The distances and directions of the base stations from Little Wyvis are shown in the scaled diagram below. As far as is possible, the base stations are evenly distributed around the survey point and heights measured from each base station were within +/-0.02m of the mean result for the summit of Little Wyvis.



The results for Little Wyvis are tabulated below:

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	242958.003	0.002	864480.066	0.002	763.009	0.003

The data for the summit of Little Wyvis recorded by a hand-held Garmin GNSS receiver was:-
 Garmin Oregon 450 NH 42959 64469 Accuracy: averaged Height = 765m

5) Summary of Operating Conditions

Variable	GS15 on Little Wyvis
Data collection summit (min)	126
Number of Base Stations used in Processing for all points	9
Epoch Time (sec)	15
Tropospheric Model	Computed
Cut off Angle (degs)	15
Geoid Model	OSGM15

6) Discussion of Results

The summit position of Little Wyvis was the top of a boulder and consequently the height uncertainty associated with locating this position was estimated to be no more than +/-0.002m. 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 height of the summit is therefore: $(0.05^2 + 0.002^2)^{0.5} = 0.05m$.

The measured height of Little Wyvis was 763.0 +/-0.05m and with the summit position so well defined we are confident that this hill is over 2500 feet (762m).

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 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.	Height Difference U metres	Separation D_{ij} metres
Ullapool	ULLO	43		
Loch Carron	LCAR	55	0.0026	0.0111
Fort Augustus	FAUG	56	-0.0150	0.0182
Helmsdale	HELS	80	0.0015	0.0019
Kinlochbervie	KINL	94	-0.0031	0.0081
Buckie	BUCK	101	-0.0183	0.0189
Braemar	BRAE	103	-0.0186	0.0215
Arisaig	ARIS	109	-0.0176	0.0239
Thurso	THUS	118	-0.0032	0.0040

The results for Little Wyvis show a consistent dataset as all measured OS Base stations are within 0.03m distance and height of the OS actual values.

8) Summary of Heighting Results

Little Wyvis was measured to be **763.0+/-0.05m** and the summit is an embedded bolder within the cairn at NH 42960 64469*.

Little Wyvis is above 2500 feet (762m) in height and therefore remains a Corbett.

The result has been accepted by Ordnance Survey and forwarded to OS Cartography for the relevant map change.

9) 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.

*grid references for use with Garmin hand-held receivers

John Barnard and Graham Jackson, 05 April 2017

Appendix



Measuring the offset for the Leica Viva GS15 on the summit of Little Wyvis



Leica Viva GS15 on the summit of Little Wyvis with Ben Wyvis behind



Summit of Little Wyvis with the Cairngorms in the distance