

Survey of Waun Camddwr

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1) Introduction

Waun Camddwr (Hill Number 2118, Section 30E, OS 1:50000 Maps 124/125, OS 1:25000 Map 23E, Grid Ref. SH847205) is listed as a Nuttall (a hill in England and Wales at or over 2000feet in height and with 15m or more of drop) in the Database of British and Irish Hills with just 15m of drop. Myrddyn Phillips had previously surveyed this hill in 1999 using his basic levelling technique where he found the drop to be 16.2m and Summit B (see extract of the OS 1:25,000 map below) to be slightly higher than Summit A. It was Myrddyn's surveys that persuaded Anne and John Nuttall to add this hill to their list.

John Barnard visited this hill during 2014 and with an Abney level measured the summit to be the top of a large rounded rock at SH 84731 20556 which was measured to be higher by 0.20m than a rocky outcrop about 50m SSW.

The purpose of this survey was to identify the position of the summit of Waun Camddwr and measure accurately its drop in order to confirm this hill's Nuttall status.

2) Equipment used and Conditions for Survey

A Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" E-staff extendable to 5m were used to determine the positions of the bwlch and summit, and also to line survey between these two points.

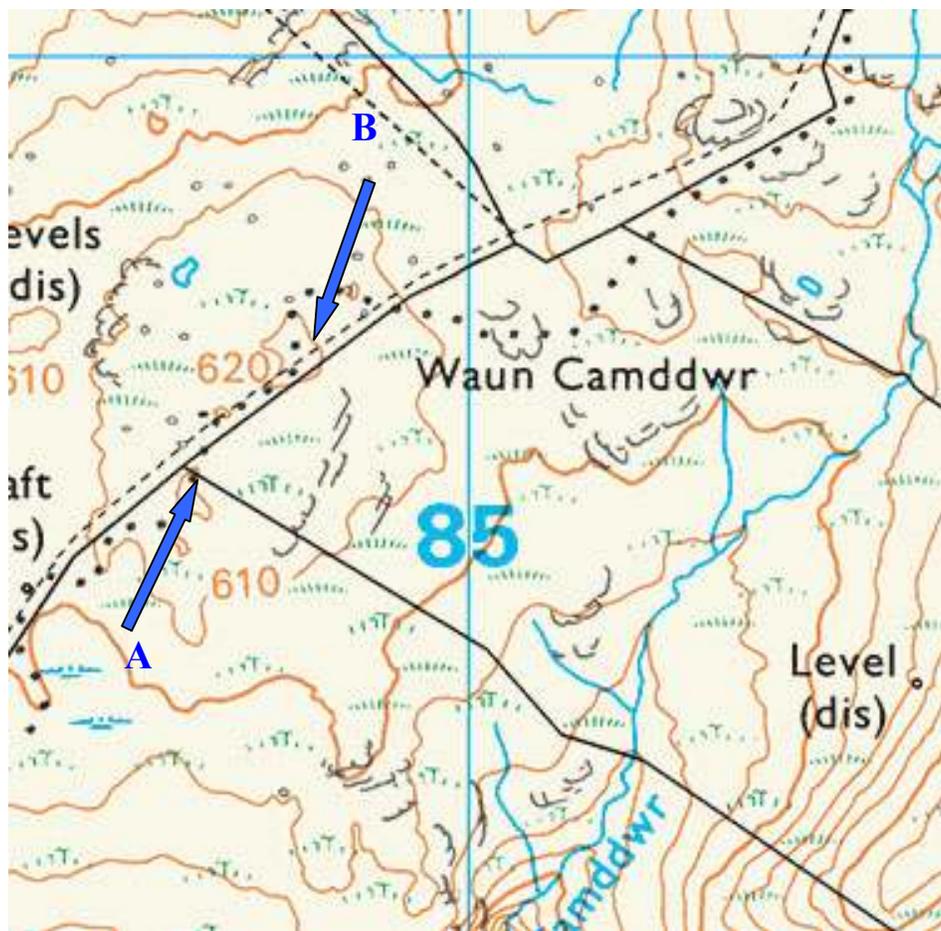
Absolute heights were measured using a Leica Geosystems Viva GS15 Professional receiver and a Trimble GeoXH 6000 receiver. Both instruments are dual-frequency, multi-channel instruments, which means they are capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receiving 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 stand-alone instruments they are capable of giving position and height to an accuracy of about two metres and five metres respectively. 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". Despite the on-board features of the Viva GS15 and GeoXH 6000 receivers, there are still sources that create residual errors. To obtain accurate positions and heights, corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from the Ordnance Survey which were post-processed using Leica Geo Office 8.3 software for the GS15 data and Trimble GPS Pathfinder Office processing software for the GeoXH 6000 data.

Conditions for the survey, which took place between 12.00hr and 17.00hr BST were good. The weather was sunny, 10 degrees Celsius with a strong breeze that had a significant chilling effect. With a clear blue sky, visibility was excellent to carry out optical work with level and staff.

3) The Survey

3.1) Character of Hill

Waun Camddwr lies at the southern end of the Aran ridge than runs from the villages of Llanuwchllyn in the North to Dinas Mawddwy in the South, a distance of about 13km. Towards the southern end of this ridge, just South of Aran Fawddwy lies Cwm Cywarch, the head of the valley where the Aran ridge continues South on its western side. The eastern side of the Aran ridge is characterised by deep cwms surrounded by high crags, but the western side is more gentle and grassy. Although the flanks of Waun Camddwr fit with the description for the Aran ridge, its summit and bwlch lie in a more open and somewhat boggy area. The terrain here is a mixture of mostly grass with a few rocky outcrops. An extract of the OS 1:25000 map showing the summit and bwlch is presented below.



The summit area is marked with a number of 620m contour rings and it is not clear from the map which is the highest point. Prior to this survey, the highest point found by a number of previous visitors, defined as **Summit A**, is that located near to the fence junction, and to the North (extract of OS 1:25,000 map above has the fence line incorrectly placed, whilst the OS enlarged Geograph map has the position of this fence as it is on the ground) of the fence running in the SW to NE direction. This is also the summit described by John and Anne Nuttall in 'The Mountains of England and Wales Volume 1: Wales'. **Summit B** is an alternative summit that was first identified as the

potential highest point by Myrddyn Phillips as a result of his basic levelling survey which lies just North of the ridge fence and about 200m NE of **Summit A**. The definitions **A** and **B** will be used subsequently in this report. Note that the fence that runs NW to SE is positioned incorrectly on the 1:25,000 map. Summit A lies about 50m NE of this fence. A third top **Summit C** (not labelled on the above map) lies about 50m South of the fence and is marked with a cairn.

If only access to Waun Camddwr is required, then this is best achieved from the car park at the end of the minor road that leads North in Cwm Cywarch. A farm track continues North from the car park followed by a way-marked footpath leading NW into the cwm. Having passed the Creigiau Camddwr on your right, the path leads out into more open ground at the bwlch between Glasgwm and Waun Camddwr. A path by a fence is followed in a NE direction to the summit and then to the critical bwlch of Waun Camddwr.

3.2) Summary of Survey Method

The survey commenced at the summit area where two candidates for the highest point were identified using the Leica NA730 level and staff. (These were defined as Summits A and B as described in the previous section.) At this stage the measurements had suggested that Summit A was the higher, but more detailed measurements later showed that this was not true.

Next the survey moved to the bwlch which was quickly identified with level and staff to be within a narrow gully on the South side of the fence. The Leica Viva GS15 was set up directly over the bwlch and GNSS data were recorded there. GNSS data were also collected from the top of an adjacent rock using the Trimble GeoXH 6000, having measured a height correction from this position to the bwlch.

In order to measure the drop for Waun Camddwr, a line survey was then carried out from the bwlch to Summit B and then on to Summit A, followed by Summit A to Summit B. Finally absolute heights for Summit B were measured by recording GNSS data for both the Leica Viva GS15 and Trimble GeoXH 6000 receivers.

3.3) The Bwlch

The hill to hill direction for the bwlch follows the line of the fence, that is SW to NE. If one follows this fence from the summit area of Waun Camddwr to the bwlch, there appears to be two possible areas for its location. Both of these are identified with gullies perpendicular to the line of the fence. The first objective of the bwlch survey was to identify which of these gullies contains the critical bwlch. The NA730 level was set up on its tripod at a convenient point between the two gullies and staff readings were taken in each at the highest points perpendicular to the line of the fence. The results were:-

Staff reading in West gully = 2.55m

Staff Reading in East gully = 4.34m

The West gully is 1.8m “higher” than the East gully and therefore could be rejected as containing the critical bwlch. The survey now focussed on the East gully. Having set up the level at a suitable position near the East gully, staff measurements were taken at about 1m intervals along the gully up to the fence. The highest point in the valley to valley direction was found to lie between a marshy area and a craggy/grassy mound quite near to the fence. The Leica Viva GS15 was set up on the “short tripod” configuration over this point and GNSS data were collected for 30 minutes. A photograph of this is shown in Appendix 1.

Since the heather at the bwlch position was quite deep, the Trimble GeoXH 6000 was set up on a rock a few metres away from this point, where the receiver had a much clearer view of the sky, to improve satellite reception. GNSS data were collected for 5 minutes. The height correction to the bwlch was made by staff measurements. These were:-

Staff reading at bwlch = 1.334m

Staff reading on rock at GeoXH 6000 placement = 1.123m

Correction for height measured by GeoXH 6000 = -0.211m

The ten-figure Grid References measured for the bwlch were:-

Garmin Montana 600	SH 85074 20712	Height = 611m
Garmin Etrex 20	SH 85071 20711	Height = 611m
Garmin Oregon 450	SH 85072 20711	Height = 606m

The position and height data for the bwlch that were recorded by the Leica Viva GS15 was post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the nine nearest base stations under 100km distance and the Hopfield model for tropospheric correction. These results and for the Trimble GeoXH 6000 processed in Trimble GPS Pathfinder Office using the five nearest base stations are given in the table below:-

Tape Reading for GS15 set up = 0.536m

Vertical offset for antenna = 0.255m.

Total vertical offset = 0.791m

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	285069.397	0.002	320707.128	0.001	606.220	0.012
GeoXH 6000	285077.192		320694.505		606.277*	

* Height corrected by -0.211m

The height of the bwlch is 606.22m

3.4) The Summit

Three potential candidates, Summits A to C inclusive, were identified as contenders for the highest point of Waun Camddwr. The Leica NA 730 level was set up on its tripod close to Summit B and staff readings were taken at each of the candidates. The readings were:-

Staff reading at summit A = 0.138m

Staff reading at summit B = 0.28m

Staff reading at summit C = 0.440m

(Summit B is about 200m distant from Summit A and the staff reading could only be read to a minimum of centimetre accuracy).

Photographs for the above measurements are shown in Appendix 1.

Summit C is lower than summit A by 0.30m and is in broad agreement with Abney level measurements taken previously. Since Summit C is clearly lower, no further measurements needed to be taken and this point was rejected as a candidate for the hill's summit.

Next the level was set up on its tripod adjacent to summit B and staff readings were taken in order to identify the highest point. After this the line surveys from bwlch to summit and between the two summits A and B, were carried out (see Section 3.5 in the report).

The ten-figure Grid References recorded for the **summit A** are:-

Garmin Montana 600	SH 84729 20555	Height = 622m
Garmin Etrex 20	SH 84729 20554	Height = 623m
Garmin Oregon 450	SH 84728 20553	Height = 628m

The ten-figure Grid Reference recorded for high point **summit C**, 50m SSW of **summit A** is:-

Garmin Oregon 450	SH 84717 20506	Height = 626m
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The ten-figure Grid References recorded for the **summit B** are:-

Garmin Montana 600	SH 84833 20714	Height = 625m
Garmin Etrex 20	SH 84831 20714	Height = 622m
Garmin Oregon 450	SH 84832 20712	Height = 627m

The Leica Viva GS15 was then set up over the summit B on the “short tripod” configuration and a photograph of the setup is shown in Appendix 1. The position and height data for the summit that were recorded by the Leica Viva GS15 were post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the nine nearest base stations under 100km distance and the Hopfield model for tropospheric correction. These results and for the Trimble GeoXH 6000, also placed on the same summit and processed in Trimble GPS Pathfinder Office using the five nearest base stations are given in the table below:-

Tape Reading for GS15 set up = 0.396m

Vertical offset for antenna = 0.255m.

Total vertical offset = 0.651m

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	284828.716	0.002	320709.884	0.001	621.666	0.008
GeoXH 6000	284828.699		320709.770		621.552	

The height of Waun Camddwr is 621.67m.

3.5) The Line Survey

This procedure commenced at the bwlch where a staff reading was taken from this point with the NA730 level on its tripod set up in a convenient position towards the hill. Once a set of readings had been taken (Backsights BS) the staff was then moved to an uphill position, but the level not moved apart from a rotation through 180 degrees to take another set of readings (Foresights FS). This process of alternately moving the staff and level was repeated uphill until the final reading was taken with the staff on the summit B position. Next the procedure was repeated from this summit to Summit A and then repeated in the reverse direction. Readings were taken from the horizontal and also the lower and upper stadia lines of the level to provide a check on any staff misreadings and to improve accuracy. If in any set of three readings the average was greater than 1mm different from the horizontal reading, then that set was remeasured.

The results for the line surveys are shown in Appendix 2. The drop for Waun Camddwr was measured to be 15.46m. However the line surveys between the two summits were inconclusive since one showed summit B to be higher by 0.004m and the other lower by 0.002m! Essentially they are the same height within the limits of the measurements taken.

4) Summary of Operating and Process Conditions

	GS15	GeoXH 6000
Data Collection bwlch (min)	33	5
Data collection summit (min)	32	5
Number of Base Stations used in Processing for all points	9	5
Epoch Time (sec)	15	1
Tropospheric Model	Hopfield	Unknown
Cut off Angle (degs)	15	5

5) Discussion of Results

The line survey could not determine which of the two summits A and B were the higher as the height difference was too small for the line survey technique and equipment we were using. It may be possible to refine the technique used to improve accuracy; for example using survey bolts for staff placements, equalizing the backsight to foresight measurement distances to eliminate any error in the alignment of the optics in the level etc. However, we felt that we may not be able to improve on the conclusion that the two summits were the same height and therefore do not plan to make any further measurements.

The staff measurements taken at the beginning of the survey indicated that the difference in height between summits A and B was greater, that is 0.14m. However, this anomaly arose from the fact that at that point we had not surveyed summit B accurately to find the highest point. The initial staff reading had not been placed on the highest point of summit B.

The line survey measured the drop of Waun Camddwr to be 15.464m. Ideally a line survey should have been carried out in the opposite direction so that a closing error could be obtained. Unfortunately, time did not allow us to do this, but typically we would expect an accuracy to within a few centimetres. However, the drop calculated from the height measurements using the Leica

Viva GS15 was 15.446m and is in excellent agreement with the line survey, the difference between the two measurements being just 0.02m. The drop of 15.3m calculated from the Trimble GeoXH 6000 measurements is also in good agreement.

We estimate the measurement uncertainty associated with a 30 minute data set for the Leica GS15 to be +/-0.07m. We also estimated that the uncertainty in height for the location of the bwlch and summit were +/-0.05m and +/-0.01m respectively. Therefore, we estimate the total uncertainty in height for the measurements of the bwlch and summit to be +/-0.09m and +/-0.07m respectively. The uncertainty in height for measurements taken by the Trimble GeoXH 6000 is +/-0.2m.

The height of Waun Camddwr was measured to be 621.67+/-0.08m and 621.6+/-0.2m with the GS15 and XH 6000 respectively and is therefore in good agreement.

The height of the bwlch was measured to be 606.22+/-0.09m and 606.3+/-0.2m with the GS15 and GeoXH 6000 respectively. Again the datasets are consistent and in good agreement.

The calculated drops from the GNSS data for the GS15 and GeoXH 6000 surveys are 15.45+/-0.11m and 15.3+/-0.3m respectively. Again these datasets are in good agreement and are consistent with the line survey value of 15.45+/-0.02m.

6) Summary and Conclusions

The **summit** of **Waun Camddwr** is at grid reference * SH 84729 20554 and is the top of a rocky outcrop. Its height is **621.67+/-0.07m**.

There is an **alternative summit** of **Waun Camddwr** at *SH 84832 20714 and is also a top of a rounded rock. Its height is **621.67+/-0.07m**.

Within the accuracy of the measurement techniques it was not possible to differentiate a height difference between the two summits.

The **bwlch** of **Waun Camddwr** is at grid reference *SH 85073 20711. Its height is **606.22+/-0.09m**

The **drop** for **Waun Camddwr** is **15.45+/-0.11m** and therefore this hill **retains its Nuttall status**.

* NB average hand-held Garmin GPS grids are quoted in the summary.

John Barnard, Graham Jackson and Myrddyn Phillips, 15 June 2015

Appendix 1



Surveying from Summit A to Summit C, the top 50m SSW. Glasgwm in the background



Surveying from Summit A to Summit B, Aran Fawddwy in the background



Leica GS15 set up at Bwlch



Leica GS15 Tape reading for Bwlch



Leica GS15 set up on summit B



Tape Reading for GS15 on summit B

Appendix 2

Title:- Survey of Waun Camddwr

Instrument:- Leica NA370 Automatic level

Date:-

22/04/2015

Point Number	Horizontal Line		Lower Stadia Line		Upper Stadia Line		Mean BS metres	Mean FS metres	Height Difference metres
	Backsight BS metres	Foresight FS metres	Backsight BS metres	Foresight FS metres	Backsight BS metres	Foresight FS metres			
Bwich to Summit B									
1	4.079	1.690	3.992	1.442	4.168	1.937	4.080	1.690	
2	1.315	0.262	0.984	0.239	1.645	0.286	1.315	0.262	
3	3.816	0.202	3.725	0.170	3.911	0.235	3.817	0.202	
4	4.634	0.563	4.392	0.502	4.875	0.623	4.634	0.563	
5	4.630	0.295	4.422	0.272	4.840	0.319	4.631	0.295	
							18.476	3.012	15.464
Summit B to Summit A									
1	0.453	2.237	0.433	1.751	0.473	2.725	0.453	2.238	
2	1.855	0.077	1.385	0.062	2.335	0.094	1.858	0.078	
							2.311	2.315	-0.004
Summit A to Summit B									
1	0.077	3.579	0.062	3.432	0.094	3.727	0.078	3.579	
2	0.518	2.272	0.455	1.945	0.580	2.599	0.518	2.272	
3	3.884	0.780	3.712	0.562	4.057	0.999	3.884	0.780	
4	2.673	0.519	2.493	0.485	2.854	0.554	2.673	0.519	
							7.153	7.151	0.002