Levelling – An Introduction

Purpose

a) To find the relative heights of things around a site.
b) To find the absolute height of an object on site relative to a nationally adopted scale.

The Equipment

1) The Level

An telescope which can be extremely accurately set so it is horizontal, has a set of cross-hairs, and can be turned through 360° horizontally.

2) The Tripod

A fully adjustable 3-legged stand on which the level sits, so that the level:

a) is roughly horizontal, prior to fine adjustment;
b) is at a height at which the user can see through it easily.

3) The Staff

A measuring stick, usually 4m tall, and clearly marked in divisions of 10mm (allowing readings to be taken to 1mm by interpolation), which is held vertically.

4) Data

This is only needed to find the absolute heights of objects, by comparing the relative heights of the thing whose height we want to know and an object of known height (a benchmark). Data is provided by Ordnance Survey, and is expensive.

How does it work?

a) Levelling does nothing more than tell you how far something (e.g. the top of coping stone) is away vertically from an imaginary horizontal line. To get any useful information requires you to gather the correct measurements and interpret the measurements correctly.

10 easy steps to set-up the level and tripod

1) Extend all legs of the tripod to their full length.
2) Splay the legs slightly apart so the tripod is stable and dig the feet in to the ground, if possible, by standing on the plate above each point.
3) Adjust the length of the legs so that the top of the tripod is roughly level and no higher than your chin.
4) Remove the level from the carry case carefully, checking that the thread on the base of it is clean.
5) Sit the level centrally on top of the tripod, and hold it there with one hand.
6) With your other hand, reach between the legs of the tripod for the retaining screw. Lift this and screw it in to the level until the level is locked tightly on to the tripod.
7) By looking at the bubble on the level, further adjust the legs of the tripod to make it even more horizontal.
8) Swivel the telescope bit of the level so it is pointing out over one the levelling screw that the bubble is closest to.
9) Adjust this screw to bring the bubble towards the centre of the target circle.
10) Adjustment at 90° to the direction the bubble was travelling in is achieved by twisting the other 2 levelling screws simultaneously in opposing directions.

When the bubble is dead centre on the target circle, the user should focus the cross-hairs and then the image. The level is then ready for use.

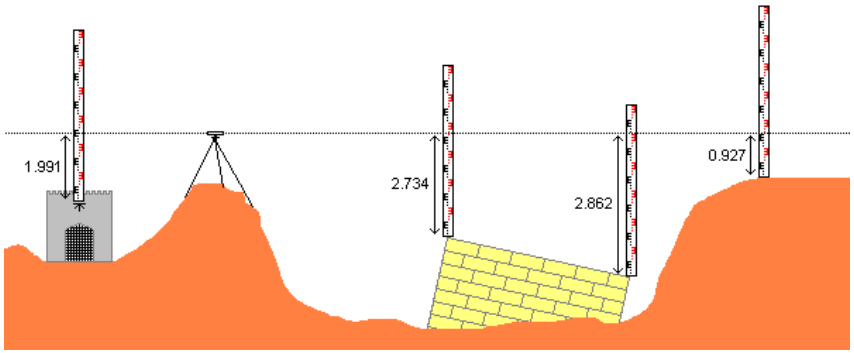
5 very easy steps to setting-up and using the staff

1) Go to the position indicated by the surveyor.
2) Extend the staff, locking each section in place at its full extension, to make the staff reach above the height at which the level is.
3) Hold it vertically on the spot required, using the bubble on the back to check it is vertical. Alternatively, sway the level back and forward slowly.
4) Ensure the face of the staff with large writing on it is facing the level.
5) Keeping your hands off the front face of the staff.

Recording results

Results are taken in metres and millimetres; never centimetres, inches, andabits, etc.

Example 1: Relative levels (e.g. is the brickwork pissed?)



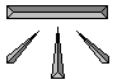
We can tell the bricklayer that there is a difference of height between:

a) one end of the wall and the other of 0.128m (2.862 – 2.734);
b) the low end of the wall and the top of the bank of 1.935m (2.862 – 0.927);
c) the high end of the wall and the top of the bank of 1.807m (2.734 – 0.927).

Example 2: Absolute levels (e.g. is that brickwork going to be underwater?)

Often we are told a height to which a canal trust wants something to be built. The figures taken in the first example would be useless: we would never be able to set up the level in exactly the same position again, and our results would be meaningless to anyone else.

The Ordnance Survey therefore defined the height of a place many years ago, and all heights can be taken relative to this position by levelling. Therefore, if we are told that we need to build a canal basin with water level of 10.400AOD, this means we must build the basin so that the water level is 10.400m **a**bove **o**rdnance **d**atum, which is a rock at sea level in Cornwall (i.e. it is 0.000AOD).



Rather than have to take a level all the way from Cornwall each time, the Ordnance Survey very kindly have scattered hundreds of benchmarks round the country, and worked out their heights for us. Very unkindly, they charge us loads to find out what height they are at. We can then take levels from these benchmarks of known height to our site.

So, if we know that the benchmark on the castle is at 10.014AOD, we can find that:

Height	Notes	Reading	+/-	Reading
10.014	Castle benchmark, supplied by OS			
12.005	Height of level	10.014	+	1.991
9.271	Left end of brickwork	12.005	-	2.734
9.143	Right end of brickwork	12.005	-	2.862
11.078	Top of bank	12.005	-	0.927

As the canal trust wanted a water level of 10.400AOD, we can tell them that the bank is high enough, but that their wharf wall will be underwater.

Example 3: Moving around site

1) Up to now we have only had the level occupy one position. We've been able to see the two or more things we need to compare because we've had clear sightlines from the level, no huge variations in altitude, and no huge distances (i.e. not more than 50m);

So the 2nd Law of Jervis dictates that we are often going to need another technique:

1) set up the level;
2) take a sight back to the first position (usually a bench-mark), known as a back-sight;
3) move staff past level to next required position (or an arbitrary position to get round an obstacle);
4) take a sight forward to the staff, known as a fore-sight;
5) keep staff stationary;
6) move the level past the staff to a position halfway between the staff and the next required position;
7) set up level again;
8) take back-sight to the staff that is still in the same position as when the previous reading was taken.

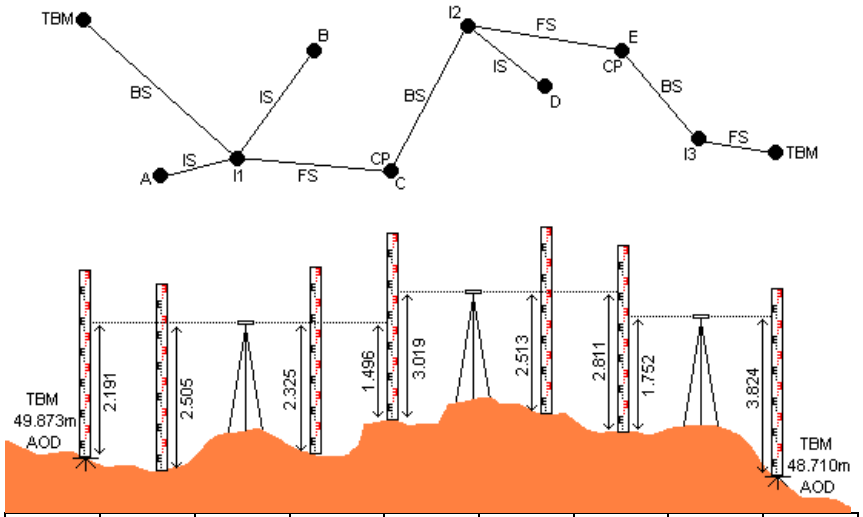
Repeat steps 3) – 8) as many times as required, progressing towards the distant point you want to compare.

It is good practice to continue from your distant point either back to your original bench-mark (or position of known height), or continue to another if it is more convenient. The accuracy of your measurements can then be checked, and adjusted appropriately.

An acceptable error (in mm) = $6 \times \sqrt{}$(number of positions the level has occupied).

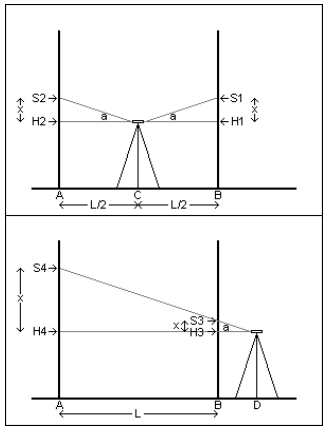
These procedures can also be used with relative heights, for example, to compare the height of an flood weir on a pound and the weir crest on a bywash that are a mile apart. Remember to return to your starting point to check your answer.

Results are entered in a level book, where each row of the table corresponds to a staff position. A number of checks should be performed at the end, and these are illustrated in the example overleaf.



Back-Sight	Inter-mediate Sight	Fore-Sight	Rise	Fall	Initial Reduced Level	Adjust-ment	Adjusted Reduced Level	Remarks

Back-Sight	Inter-mediate Sight	Fore-Sight	Rise	Fall	Initial Reduced Level	Adjust-ment	Adjusted Reduced Level	Remarks
2.191					49.873	-	49.873	TBM 49.873
	2.505			0.314	49.559	+0.002	49.561	A
	2.325		0.180		49.739	+0.002	49.741	B
3.019		1.496	0.829		50.568	+0.002	50.570	C (CP)
	2.513		0.506		51.074	+0.004	51.078	D
1.752		2.811		0.298	50.776	+0.004	50.780	E (CP)
		3.824		2.072	48.704	+0.006	48.710	TBM 48.710
6.926 8.131 -1.169		8.131	1.515 2.684 -1.169	2.684	48.704 49.873 -1.169			Check



Two Peg Test
Strictly this check should be carried out every time the level is used. Following the diagrams on the left:

If (S1 – S2) = (S3 – S4) then the instrument is in adjustment. If (as is more likely), they don't agree, the difference in the two results will indicate the size of the collimation error, e. If this is less than +/- 3mm over approx 60m then the instrument does not need readjusting.

Boring Things
The level is expensive and fragile: look after it, stay within sight of it, and cover it from heavy rain. The sachet of silica gel in the carry-case absorbs moisture which can cause misting. Marcus Jones 26/9/2000