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"TAKING LEVELS" ON THE FARM

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"Taking levels" or "levelling," is the art of measuring differences in elevation or level of points on the surface of the earth. It also includes the setting of marks or pegs at required elevations or levels. It is an essential preliminary to most farm construction jobs, e.g., drainage, irrigation, boxing for building foundations, laying concrete floors or paths.

No special training or costly equipment is needed for taking levels sufficiently accurately for farm construction work. Any farmer can learn to do it with a little practice. This bulletin sets out to explain the simple principles on which the taking of levels is based, and explains how to do it with simple equipment.

To take levels, it is necessary first to establish or set out a level, or horizontal line, relative to which elevations or levels are measured. This can be either an imaginary line through the sights of some sighting instrument, or an actual line such as one edge of a piece of timber. Examples of simple equipment for establishing a level line will now be described, while in each case the method of using it to solve the fundamental problem in levelling, i.e., how to find the difference in level between any two points, will also be dealt with.

The Water Level.

This instrument is based on the principle that the surface of water at rest is level. In this simple instrument, shown in Fig. 1, two glass tubes are inserted into the ends of a length of ½ inch rubber tubing. These tubes are clamped to the ends of a piece of 4 inch x 1 inch board about 4 feet long. This board is mounted on a tripod in such a manner that it will swivel around a full circle in a horizontal plane, and can tilt a little in a vertical plane, but can be locked in any position with thumb screws. The rubber tube is filled with water, preferably coloured with dye to make it readily visible, so that the water surface appears in both glass tubes. The rubber tube must be squeezed to remove air bubbles. Corks are fitted in the glass tubes, during transport, and these tubes can be withdrawn within their clamping blocks when not in use.

A measuring rod or levelling staff is needed to use with the water level, or indeed any level. A simple staff can be made from a good straight piece of 2 ins. x 1 in. timber, about 8 or 9 feet long, marked off in feet, inches and quarters of an inch; or, more conveniently it could have 3-foot dressmakers' rulers screwed end to end on one face of the timber.

A pointer for use with the staff is best made in the form of a Tee, the cross-piece consisting of a piece of 2 ins. x ⅜ in. timber, 18 ins. long, and painted white, while the vertical leg made of similar timber can be 12 ins. long. The cross-piece can, if desired, have a red or black line painted along it.

Fig. 2 shows the method of using the water level to find the difference in level between any two points A and B on the ground. First drive in two level pegs (2 ins. x 1 in. timber, 12 ins. long and pointed) approximately to ground level at A and B. This is necessary to define the ground surface definitely for the later construction work. These pegs will be difficult to see from a distance, so larger pegs of 3 inch x ½ inch timber should be driven near them, sticking up out of the ground, to mark their position. These latter are called "marker" pegs, or "witness" pegs, and the descriptive number or letter of the level pegs may be inscribed on these "witness" pegs.

Now set up the water level, with tripod legs firmly pressed into the ground, about midway between A and B. Remove the corks, and tilt the level so that the water is visible in

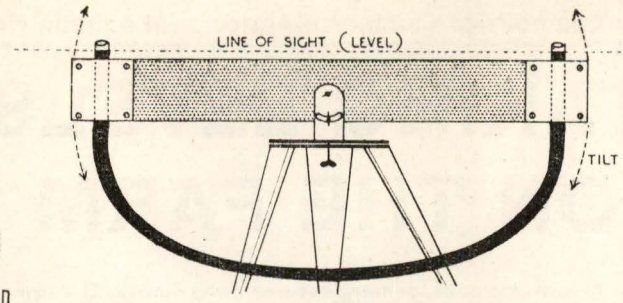

Fig.1

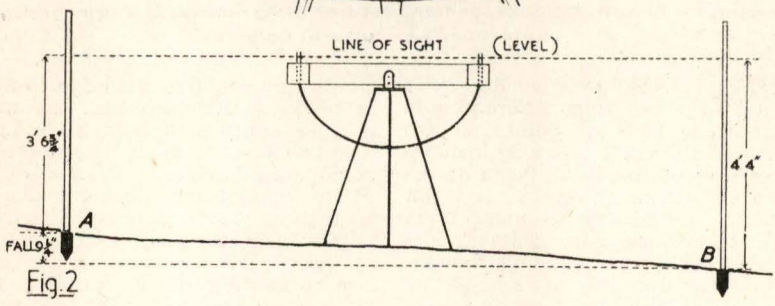

Fig.2

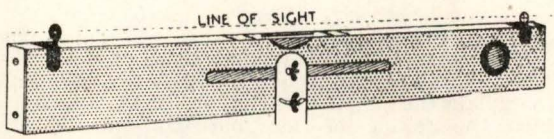

Fig.3

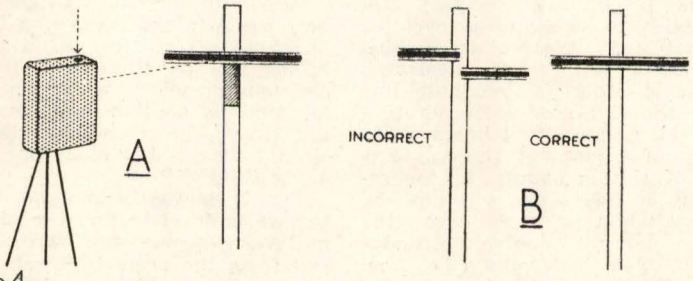

Fig.4

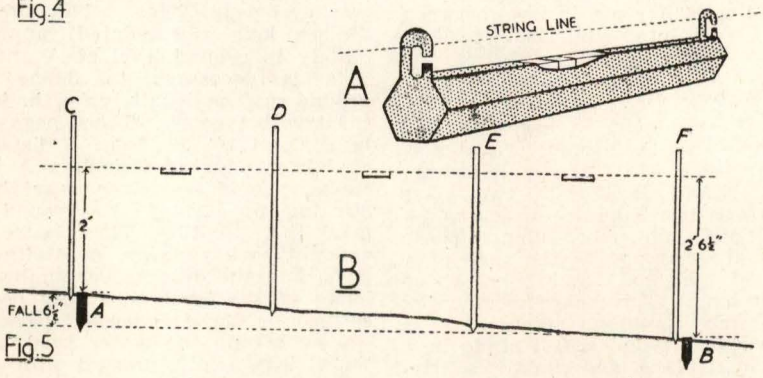

Fig.5

both glass tubes. Have an assistant hold the measuring rod or levelling staff upright on the top of Peg A. Stand at the opposite end of the instrument from A, swivel it so that it points at the staff, and, standing about 3 feet back from the instrument, sight along the tops of the two water surfaces at the staff on which the assistant is holding the pointer. The line of sight thus established is level. Direct the assistant to move his pointer up or down until one edge of the cross-piece, or the black line painted on it, appears to be exactly in line with the two water surfaces. The assistant then reads the measurement where the top edge of the pointer cuts across the staff, reading to the nearest quarter of an inch. Repeat the sighting and readings as a check. Suppose an accuracy to within ¼ inch of the correct difference in level is readily obtained with a little practice; but differences in level of pegs several chains apart can also be measured, with some loss of accuracy, but still within the permissible range of error for most farm constructional jobs. The water level has a great advantage over many other instruments, in that the water surfaces are always level, and thus there are no adjustments to make. It suffers somewhat from vibration of the water surfaces in windy weather.

The Carpenter's Level with Sights and Tripod.

The carpenter's level depends on the well known principle of the spirit-bubble tube for establishing a level line. This consists of a slightly

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Fig. 1.—Water level mounted on tripod head that permits swivelling and tilting.

Fig. 2.—Finding difference in level between two pegs. Peg B is 9¼ inches lower than Peg A.

Fig. 3.—The carpenter's level with sights, mounted on a tripod head similar to Fig. 1.

Fig. 4 (A)—Taking a sight with the Cowley automatic level.

Fig. 4 (B)—Showing correct and incorrect settings of pointer.

Fig. 5 (A)—The line level.

Fig. 5 (B)—Finding difference in level between two pegs with the line level. Peg B is 6¼ inches lower than Peg A.

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the reading on A, obtained thus, is 3 ft. 6¾ ins. as shown in Fig. 2, i.e., peg A is 3 ft. 6¾ ins. below the level line of sight.

Now get the assistant to move to B and hold his staff on top of the peg, and repeat the procedure. Suppose the reading on the staff at B is 4 ft. 4 ins., as shown, i.e., peg B is 4 ft. 4ins. below the level line of sight. Then, as by subtraction the difference in levels of pegs A and B is the difference between 4 ft. 4 ins. and 3 ft. 6¾ ins., i.e., 9¼ ins., it is seen that the top of peg B is 9¼ ins. lower than the top of peg A. To avoid falling into a simple and common error, it should be carefully remembered that the peg on which the staff reading is higher is actually the lower of the two pegs. i.e., B is lower than A.

With pegs up to one chain apart, curved glass tube filled with spirit, set in the wooden body of the carpenter's level in such a manner that, when the bubble appears midway between two marks on the tube, the long edges of the block are truly horizontal. In good quality levels, the bubble is mounted so as to permit readjustment of the bubble tube setting if necessary.

Pairs of sights, consisting of a foresight with a horizontal crosswire, and an aperture backsight, can be purchased from hardware mechants and clamped on each end of the level. When the carpenter's level is held so that the bubble is in the centre of its run, the line of sight, through the aperture to the cross-wire, will be truly level if the carpenter's level and the sights are in correct adjustment.

For field use, the level should be

mounted on a tripod so that it can be swivelled in a horizontal circle, and tilted to bring the bubble to the centre. Such tripods are manufactured overseas for sale; but if unobtainable here the carpenter's level can be mounted on the type of tripod used for the water level, by fitting two 5/16 inch bolts with wing nuts through holes drilled in the wood of the level, and using these to clamp it to the upright portion of the tripod head, just as the board of the water level is clamped. See Fig. 3.

This instrument is used in exactly the same manner as the water level, remembering that, before taking a sight, the level must be tilted and then clamped so that the bubble is exactly at the centre. Unlike the water level, it is difficult to take accurate sights at a greater distance than about one chain, but many people find it easier to sight through the level sights than along the water surfaces of the water level. Accuracy similar to that of the water level can be attained.

The Cowley Automatic Level.

This is a new type of levelling instrument especially designed to replace the more complicated and costly surveyors' dumpy level for farm and building use.

In appearance (See Fig. 4) it is a rectangular metal box, with a small circular viewing aperture on top, and a larger circular aperture on one face, the box being mounted on a pivot pin on a low tripod in such a manner that it will swivel in a horizontal circle. The instrument is set up merely by spreading the legs of the tripod so that the pivot pin is approximately upright as judged by eye, and then placing the metal box on the tripod with the pivot pin entering a hole provided for it. There are no screws to turn or spirit bubble to centre, as the instrument contains a plumb bob, that, always hanging truly vertical, serves to establish an imaginary line at right angles to it which is thus truly level, and relative to which elevations can be measured.

The Cowley automatic level can be used to find the difference in level between two pegs A and B in a similar manner to the water level or carpenter's level with tripod and sights, the only difference being the manner in which the actual staff readings are obtained. This is done in the following manner: After setting up the instrument approximately midway between pegs A and B, as shown in Fig. 2 for the water level, direct the large circular aperture towards the staff held on peg A. On looking down through the small circular viewing window on the top face of the box, an image of each half of a pointer held against the staff will be seen, one seen reflected by a system of mirrors that includes a mirror attached to the plumb bob, and the other seen reflected through a fixed system of mirrors. See Fig. 4. If the assistant moves the pointer up and down on the staff, the two halves will appear to move further apart or closer together. Get the assistant to move the pointer until the two images coincide, when the reading of the position of the top edge of the pointer on the staff is taken. Repeat this procedure with the staff on peg B. The difference between the staff reading on peg A and the staff reading on peg B gives the difference in level of the two pegs. The procedure is actually exceedingly simple in practice, much more simple than it looks in print. Full directions are supplied with the instrument.

The Cowley automatic level will permit an accuracy of within $\frac{1}{8}$ inch at a distance of one chain if carefully used. Beyond this distance, some loss of accuracy may occur due to difficulty in setting the pointer exactly, but with a large enough pointer, it can be used for shots several chains long. Its greatest advantages for farm use are its ease of use, accuracy, low cost compared with a surveyor's dumpy level and absence of setting-up adjustments. On the other hand it could readily be put "out of truth" by rough handling, and is somewhat liable to vibration on a windy day.

The Line Level.

A line level consists of a small metal tube containing a spirit bubble tube, and fitted with two hooks for hanging on a taut string line (see Fig. 5), so that it will indicate when the string line is level, and thus will establish a level line relative to which elevations can be measured.

Fig. 5 shows how to use the line level to find the difference in level between two points which are again marked by driving in pegs A and B.

Get several stakes of 2 ins. x 1 in. timber about 3 feet long, preferably painted white, and drive one in firmly near peg A, and the others about half a chain apart in the direct line between peg A and peg B. Actually a minimum of two stakes would be sufficient, as they can be pulled out and used again. Make a mark on the stake C near peg A at some convenient distance, say exactly 2 feet above the top of peg A. Hold one

end of the string line on this mark (or tie it around the stake), stretch the string line so that the other end is held against the next stake D, and hang the line level exactly on the middle of the span of string (this is very important for accuracy). Raise or lower the end of the string held against stake D, until the bubble in the line level is at the centre, and make a pencil mark against the string on stake D. This mark will then be on the same level as the mark on stake C. (As a check on the accuracy of the line level, reverse it on the string and repeat, when the same mark should be obtained on stake D. If not, either correct the line level by bending one of the hooks slightly until a correct reversal is obtained, or "split the difference" between the two marks on peg D). Continue this procedure, obtaining marks on the remaining stakes E and F in this manner. Thus a level line will have been established. Measure down from the mark on the last stake E, to the top of peg B. Suppose this distance is 2 ft. 6½ ins. Then the difference in level is obviously got by subtracting 2 ft. from 2 ft. 6½ in., i.e., 6½ in., peg B being lower than peg A.

This method is very simple, the equipment costs only a few shillings, and good results are obtainable except on a very windy day. It can be used by one man. It is most important to have the line level at the middle of the span of the string, to equalise the sag. It is important also to centre the bubble very accurately.

The Carpenter's Level and Straight Edge.

This is a very similar method to the line level and string, but a carpenter's level is used, instead of the line level, tied to the top edge of a wooden straight edge (16 ft. x 6 ins. x 1 in.) which is held between the stakes. It is slow and rather cumbersome, but is accurate and unaffected by wind. To guard against errors arising from possible warping of the straight edge, it is advisable to reverse straight edge and attached level together between each pair of stakes, and if necessary to "split the difference" between the two marks on the second stake. For convenience in working, the straight edge can be supported on nails driven into the stakes.

Taking a Sequence of Levels.

In many farm levelling jobs it is necessary to find the levels of a series of points, e.g., in planning a tile drain to be constructed where the ground surface is undulating, it is usually necessary to find the levels of the ground at points one chain apart along the line of the proposed drain. This process is merely, however, an extension of the process already described of finding the difference in levels of two pegs. When using a sighting instrument such as the water level or Cowley automatic level, some time may be saved by setting up the instrument in a position where sights can be taken on to several points from the one position.

Recording the Readings.

The simplest and most direct way of recording the readings on the staff, and the differences in level, is by showing them on a simple diagram in the manner shown in Fig. 2. It is sometimes convenient to assume a definite level for one of the pegs, and from the differences in level to calculate the corresponding levels of the other pegs, e.g., if the top of peg A was assumed to be at a level of 10 ft. then the top of peg B would be at a level of 10 feet minus 9¼ ins., i.e., 9 ft. 2¾ ins. Suppose there were a third peg C whose top was then found to be 2 ins higher than peg D, then likewise its level would be 9 ft. 4¾ ins.

Putting in Pegs at Required Levels.

It is quite easy to put in a peg on the same level as another peg, e.g., for a building foundation, or to put in a peg at a required difference in level from another peg, e.g., when pegging out the line of an irrigation race on rolling country it may be necessary to give it a fall of 1 inch between succeeding pegs one chain apart.

To put in a peg B at the same level as a given peg A, set up the instrument and take a reading on to the measuring staff held on peg A. Then transfer the staff to peg B and drive the peg until the same reading is obtained as that when the staff was held on peg A.

If the peg B were instead required to be say 1 inch lower than peg A, then drive peg B until a 1 inch greater reading is obtained on peg B. Proceed similarly to obtain any other desired difference in level.

Checking the Adjustment of the Instrument.

Some sighting levelling instruments such as the carpenter's level with tripod and sights, or the Cowley automatic level, may become out of ad-

justment, i.e., the line of sight may actually be tilted upwards or downwards when the instrument indicates that it is level. It is easy to check the adjustment of the instrument in the following manner. Set up the instrument correctly midway between two pegs about 60 ft. apart. Find the difference in level of the tops of the two pegs by taking readings in the usual manner. This difference must be correct if the two sights are of equal length, irrespective of whether the line of sight is tilted up or down. Then shift the instrument near to one of the pegs, and again measure the difference in level of the pegs. This should be the same as that obtained from the first position of the instrument. If it is not, the instrument is out of adjustment, and should be corrected. With a carpenter's level and sight, this can be done by packing under one of the sights until the correct difference in level is obtained. The Cowley level should be returned to the agent for readjustment.

Checking of the adjustment of the instrument should be done very frequently.

Conclusion.

The common practice of guessing levels is inadvisable as it rarely gives satisfactory results. Levels can be taken easily by the farmer with simple inexpensive equipment.

Copies of this Bulletin may be obtained from the Secretary, Canterbury Chamber of Commerce, P.O. Box 187, Christchurch.

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