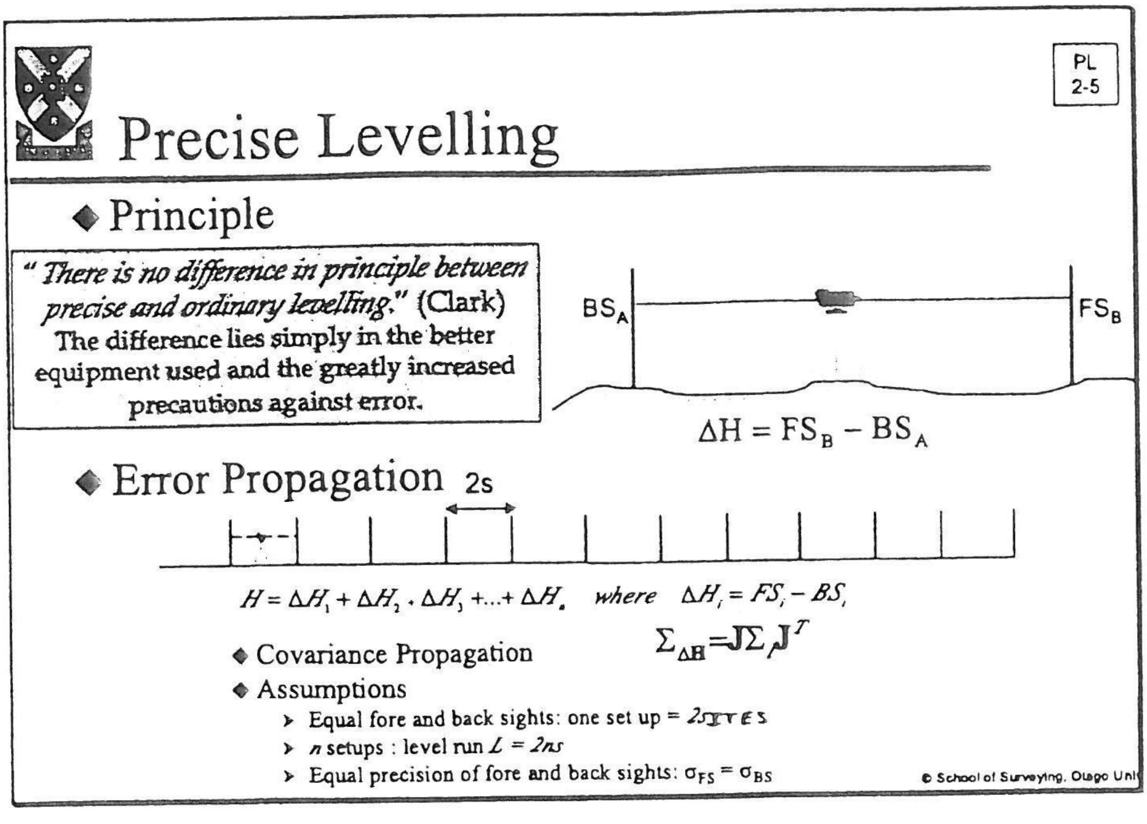
PRECISE LEVELLING :
INTRODUCTION:

The primary reference at water-level recording stations is a set of stable bench-marks, installed in locations where their level should not change. Upon initial set-up of a station, the levels of therelevant parts of the installation are established and recorded by means of accurate levelling.At least every two years, the levels of the staff gauges, sensor level, internal gauge, tower structure and benchmarks should be measured relative to each other as a check that records are not in error due to bank subsidence or other movement.Accurate levelling is thus a particularly important part of site establishment, installation andquality assurance.

Definitions

Differential levelling is the term applied to any method of measuring directly with a graduatedstaff the difference in elevation between two or more points.

Precise levelling is a particularly accurate method of differential levelling whichuses highlyaccurate levels and with a more rigorous observing procedure than general engineering levelling. Itaims to achieve high orders of accuracy such as 1 mm per 1 km traverse



A **level surface** is a surface which iseverywhere perpendicular to the direction of the force ofgravity. An example is the surface of a completely still lake. For ordinary levelling, level surfacesat different elevations can be considered to be parallel.

A **reduced level** is the vertical distance between a survey point and the adopted level datum.

A **bench mark** (BM) is the term given to a definite, permanent accessible point of known heightabove a datum to which the height of other points can be referred.It is usually a stainless steel pin embedded in a substantial concrete block cast into the ground. Athydrological stations rock bolts driven into bedrock or concrete structures can be used, butstructures should be used warily as they themselves are subject to settlement. The locations ofbenchmarks shall be marked with BM marker posts and/or paint, and recorded on the Station

A **set-up** refers the position of a level or other instrument at the time in which a number ofobservations are made without mooring the instrument.

Height of Collimation is the elevation of the optical axis of the telescope at the time of the setup.

The **line of collimation** is the imaginary line at the elevation.
Orders of levelling refer to the quality of the levelling, usually being defined by the expectedmaximum closing error.

APPARATUS:

The level, its tripod, the staff and the staff bubble are all precision items of equipment upon whichthe accuracy of the work is highly dependent. They shall be kept correctly calibrated, and be usedand stored with care.Levels shall be carried in vehicles in a padded box, case or shelf in addition to the normal case,and staves shall be kept in a canvas or plastic sleeve to prevent damage to the face and entry ofdirt.

Levels :A level is basically a telescope attached to an accurate levelling device, set upon a tripod so that it can rotate horizontally through 360°. Normally the levelling device is a bubble, but modern onesincorporate a pendulum.
There are three basic types of level,

(a) Dumpy levels

These are more basic levels often used in construction work. The telescope is rigidly attached to a single bubble and the assembly is adjusted either by means of a screwed ball-joint or byfootscrews which are adjusted first in one direction, then at 90°.

(b) Tilting levels

This type of level is fitted with a circular bubble for preliminary approximate levelling and a main bubble which is attached to the telescope. For each observation (not setup) the main bubble isviewed through an eyepiece and the telescope tilted by a fine screw to bring thetwo ends of thebubble into coincidence.

(c) Automatic levels(NI2- CARLZIESS):

This more modern type of level is now in general use. It has a compensator which consists of anarrangement of three prisms. The two outer ones are attached to the barrel of the telescope. Themiddle prism is suspended by fine wiring and reacts to gravity. The instrument is first levelledapproximately with a circular bubble; the compensator will then deviate the line of sight by the amount that the telescope is out of level.

Staves

The levelling staff is a box section of aluminium or wood, which will extend to 3 or 5 m in height by telescoping, hinging or addition of sections. One face has a graduated scale attached for readingwith the cross-hairs of the level telescope. These faces can vary in pattern and graduation; 5mmgraduations should be the maximum for accurate levelling of gauging stations.Many staves used these days are of aluminium because of its durability. However aluminium has aco-efficient of thermal expansion of :0.000023m/metre of length/°C
and this can cause some potential inaccuracies. For instance, "Survey Chief" and "Bookreades"staves are standardised at 27°C, and in very cold weather these staves could be as much as 3mmtoo short over their full length. For low temperature work consult the temperature table for eachstaff which should be with its "instruction manual" or printed on the staff itself.

Staff bubbles
These are generally a small circular bubble on an angle plate which is held against one corner ofthe staff to ensure that the staff is held in a vertical position. If the staff is not held vertical, thereading will be too large and may be significantly in error.A staff bubble shall be used at all times. If one is not available, the "chainman" (staff operator)shall rock the staff slowly back and forth about the vertical in a line towards the instrument. Theobserver notes the smallest reading which will occur when the staff is vertical.
• staves are too much of a precision item of equipment to be used in place of a slasher, vaulting pole, etc.
• staves shall be transported in their protective cases to protect the face from damage.
• wooden staves which become wet should be dismantled and dried out before storing away.
• any moisture which is evident in an instrument must be allowed to disperse by storing the level out ofits case in a warm room. Should it persist after several days the instrument may require specialistservicing.

Checking the level's accuracy
Levels can move out of adjustment so that their line of sight (line of collimation) is not trulyhorizontal. This will cause errors in readings which become greater as the viewing distanceincreases. However if a backsight and a foresight are exactly equi-distant from the instrument, theerror in each sighting will cancel each other out. This feature can be used to check the accuracy of a level by the following simple method which is depicted in figure 6.2 (from MWD, 1981):
• install three pegs or marks firmly in the ground at distances of 30 m apart in a straight line; the centre
peg is only to mark the distance, but the outside two shall be firm enough for reliable change points
• set up the level over the centre peg and read the staff on each of the outside pegs in turn. Book these
values and calculate the height difference. This will be a true height difference, as the distances are
equal and any errors will be self-compensating

• set up the level about 4 m to the far side of one of the outside pegs. Read the staff on the peg 4 m away
and then on the one 64 m away. Book these values and calculate the apparent height difference
• compare the two height differences; if the instrument is in adjustment (i.e. its collimation is true) they
will be within 5 mm.

A method for checking the level accuracy

If the instrument's collimation appears to be out, recheck by repeating the process. Then, whilstsetup at one of the outside locations, adjust the instrument (according to the manufacturer's*Levelling & Surveying*instructions) so that it reads the correct value on the far staff, checking it against the near one. Two staves are useful for this.This type of level check shall be carried out at least once per year, preferably just prior to carrying
out a round of station inspections. The details and results of the checks shall berecorded in anumbered level book and be readily retrievable as a quality record, and the date of this calibrationcheck shall also be recorded in the instrument inventory.

Lvelling procedures

(a) Setting up

• Backsight and foresight distances should be approximately equal to avoid any errors due to collimation,
refraction or earth curvature.
• Distances must not be so great as to not be able to read the graduations accurately.
• The points to be observed must be below the level of the instrument, but not lower than the height of
the staff.

Reducing the levels

Two methods are in general use; the "rise and fall" method and the "height of collimation" method.The latter reduces levels relative to the instrument height. As it has inferior in-built checks it should not be used and will not be covered here.The "rise and fall" methods shall be used for reduction of all site levelling. Reduction shall becarried out on site before packing up to ensure that the levelling has been done correctly.
• calculate the rises and fall between successive points and book them in the appropriate column (one can
determine whether each shot is a rise or fall by the following rule of thumb: a higher value on top
denotes a rise; a higher value on the bottom denotes a fall)

• add up the backsight and foresight columns for the entire traverse and note the difference between
them; this is the close
• add up the rises and falls for the entire traverse, and compare the difference between them with the
difference between the backsights and foresights; they should be the same
• carry the reduced levels in the R.L. column down the page by adding or subtracting the appropriate rise
and fall values to the successive values of R.L. The final value of the original starting point will differfrom the original value by the amount of the close.
If the levelling has been done correctly and all arithmetic reductions are correct, the differencesbetween total backsights and foresights, total rises and falls, and starting and finishing R.L.'sshould be the same. This difference is the close; and for site inspection purposes it should bewithin ± 2mm or ± 6mm, depending upon which water-level standard is being followed, ± 3mm or± 10mm.

Level books

All levelling shall be booked in either level books or levelling sheets which shall be retained aspermanent records.Level books shall be numbered so that they can be referenced on station history and inspectionforms. They should be stored in fire-proof storage as for original record. They should also include an index.

Closing error:

Using the formula. _______

Allowable Closing Error: **$E = C\sqrt{D}$(Km)**

where **C is a constant** for a particular class of levelling and **D is the distance levelled** in Kilometres.

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