**KATHMANDU UNIVERSITY**

**SCHOOL OF ENGINEERING**

**DEPARTMENT OF GEOMATICS ENGINEERING**

# FINAL REPORT ON
# FIELD PROCEDURE OF DIFFERENT BRANCHES OF SURVEYING

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# CHAPTER 1: LEVELLING

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| | |
|---|---|
| BM | Benchmark |
| BS | Backsight |
| D-Card | Description Card |
| FS | Foresight |
| LMTC | Land Management Training Center |
| m | Meter |
| MSL | Mean Sea Level |
| PBM | Permanent Benchmark |
| RL | Reduced Level |
| TBM | Temporary Benchmark |

# 1. INTRODUCTION

## 1.1 Background

Levelling is the method of establishing vertical control points. It is the process of determining difference in elevation of various points on the earth's surface (Shrestha, 1988). This procedure that involves measurement in vertical direction is carried out to find elevation of given points with respect to given or assumed datum and to establish points at a given elevation or at different elevations with respect to a given or assumed datum (Punmia et al., 2005).

Levelling has a wide application in various fields of geospatial domain. Levelling helps in determining the topographical diversification in an area. Besides this, the levelling procedure helps in locating the gradient lines for drainage characteristics of an area and it also helps in designing and laying out various construction projects like highways, canals, railways, etc. Levelling assists in calculating volume of earthwork and reservoir as well.

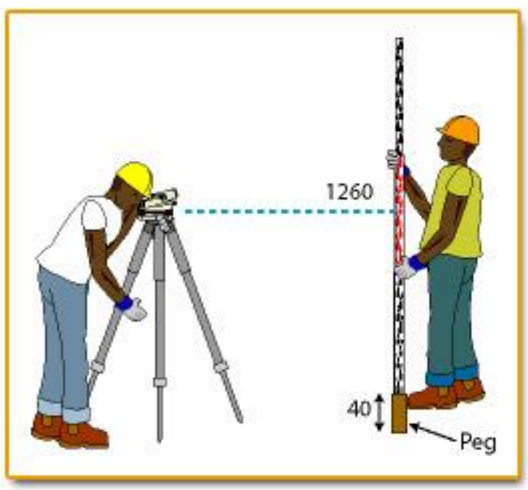


**Figure 1. Picture Depicting Field Procedure of Levelling**

This project was carried out on a hill named 'Talu Danda', a geographically diversified land, located in Dhulikhel premises of Kavre District. Nine benchmarks incorporating two permanent and seven temporary benchmarks were established whose respective elevations were determined using levelling procedure. For a group of 5 members, we were provided with Auto-level machine for carrying out fourth order levelling as well as for carrying out Profile and Cross Section Levelling near Dhulikhel Hospital.

This project became a productive approach for us as the students of Geomatics Engineering as it helped us in broadening the practical understanding of surveying, specially in the domain of establishment of vertical control points.

## 1.2 Objectives

The key objective of levelling was

- To find the elevation of points of unknown elevation with respect to point of known elevation (datum).

The secondary objectives achieved during the accomplishment of levelling are pinpointed below:

- Determination of topography of an area.
- Learned about the preparation of D-Cards of monuments.
- Learned about carrying out profile and cross section levelling and developing their respective graph plots.

## 1.3 Scope

The course of levelling was basically focused on establishing vertical control points. The monumentation used for stations were of temporary nature (wooden pegs were used). So, permanent monumentation of control point is not under the scope of the project. The preparation of Description Cards for the established monuments was incorporated under the scope of the project. Furthermore, as profile and cross section levelling was carried out on a narrow road running through the downhill, it was not possible for taking the measurements in equal lateral distance intervals from the longitudinal profile as recommended, i.e. 3 m, 6 m, 9 m, and 12 m for cross sectioning. Also, the levelling carried out was of fourth order, so the accuracy greater than fourth order was not embraced under the scope of work.

# 2. METHODOLOGY

## 2.1 Theoretical Framework

Levelling is based on the principle of making the line of sight horizontal (Roy, 1999). When the level machine is set up correctly and leveled, the bubble tube axis and the line of sight will be horizontal and the vertical axis of the instrument will be vertical, thus ensuing the line of sight in a horizontal plane, wherever the telescope is rotated.

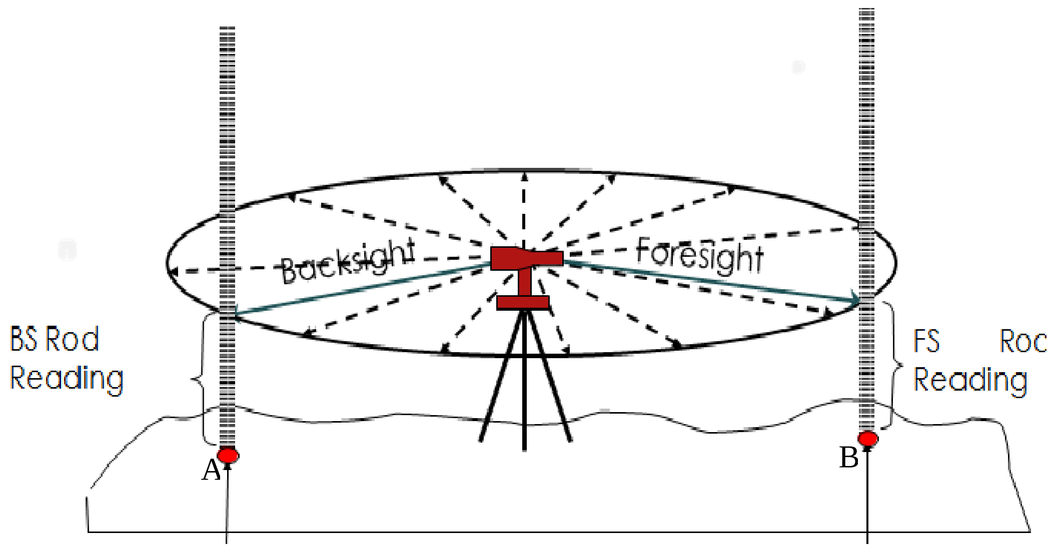


**Figure 2. Principle of Levelling**

When a level machine is setup correctly and levelled approximately midway between the benchmark (represented by A in the figure) and the point (represented by B in the figure), the elevation of the point can be ascertained by levelling procedure. From the staff held at the benchmark, a backsight is taken and the height of instrument is determined.

$$\text{HI} = \text{Elevation of Benchmark} + \text{Backsight reading}$$

On turning the telescope to bring into the staff held on point B, a foresight is taken to formulate the elevation of that point.

$$\text{Elevation of the point B} = \text{HI} - \text{Foresight}$$

**Types of Level:**

The major types of levels are highlighted below:

i) Dumpy Level: In dumpy level, telescope tube and the vertical spindle are cast as one piece. The spirit level and telescope are rigidly fixed to the support so that telescope cannot be moved from its support nor can it be rotated about its longitudinal axis.

ii) Tilting Level: In addition to bubble tube the tilting level has additional split bubble which is leveled by turning the tilting knob. The line of sight can be made horizontal by a tilting screw even though, the vertical axis is not exactly vertical. Tilting Level are commonly used for precise levelling.

iii) Automatic Level: Automatic level has a special arrangement of prisms carried on a pendulum. The prism and the pendulum is so designed that only the horizontal, level rays of light are reflected through the cross hairs to the optical center of the objective lens. Only the approximate levelling of a circular bubble is needed, then its built in compensator takes over and makes the level ready for operation automatically, in no time.

iv) Digital Level: Digital Level uses staffs with barcodes. It is operated by comparing the observed digital image of a bar-code leveling rod with a map of the barcode stored in the level's memory (electronic image processing). It removes the interpolation of graduation by a person, thus removing a source of error and eliminate risk of human error thus, increasing accuracy.

**Methods of Levelling:**

i) Direct Levelling (Spirit Levelling)

It is a method of levelling in which the vertical distances with respect to a horizontal line of sight can be used to determine the relative difference in elevation between two adjacent points. It is the most precise method of determining elevations. Direct levelling can be further classified into following types based on different working methods:

- Simple Levelling: Only one setup is done for the measurement of height difference between two points.
- Differential Levelling: More than one setup is maintained to determine the difference in elevation of two points. This method is adopted when two points who difference is elevation to be measured are far apart for each other.

- Profile Levelling: In this method of direct levelling, the elevations of the points along a given line are measured at a certain interval in order to obtain the profile of the surface of the ground along than line.
- Cross-Sectioning: Cross-Sectioning is the process of taking levels on both the lateral sides of a main line at right angles to that line, in order to determine a vertical cross section of the surface of the ground.
- Reciprocal Levelling: The difference in elevation between two points is accurately determined by two sets of reciprocal observations when it is not possible to setup the level between the two points.
- Precise Levelling: It is the method of levelling in which high degree of precision is maintained using special equipment and special precautions, to eliminate, as far as possible, all sources of error.

ii) Indirect Levelling

It is used when direct levelling becomes difficult in easily inaccessible points such as peaks, top of towers, etc. The principal methods of indirect levelling are viz.

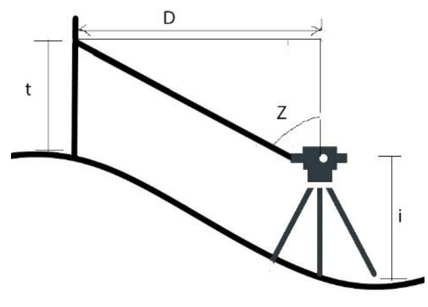


**Figure 3. Trigonometric Levelling to determine the RL of a spot**

- Trigonometric Levelling: It is the process in which the elevation of the points is computed from the vertical angles and the horizontal distances, just similar to the computation of length of any side in a triangle with proper trigonometric relations.
- Barometric Levelling: Barometric Levelling is based on the phenomenon that the difference in elevation between two points is proportional to the difference in atmospheric pressure at these points. As the atmospheric pressure doesn't remain constant in the course of a day even at a particular place, this method is relatively inaccurate, unreliable and is less used such as in cases of reconnaissance work.
- Hypsometric Levelling: In this method, difference between elevation is determined by noting down the temperature at which the water starts boiling. Boiling point of

water decreases as the altitude of the place increases. It is very rough method and is rarely used.

**Basic terms related to Levelling:**

- Level Surface: It is a continuous surface which at each point is perpendicular to the direction of gravity at that point.
- Level Line: Any line lying on a level surface is the level line. It is normal to the direction of gravity at all points.
- Horizontal Plane: Horizontal plane through a point is a plane tangential to the level surface at that point. It is perpendicular to the line of gravity.
- Horizontal Line: It is a straight line tangential to the level line at a point. It is also perpendicular to the plumb line.
- Vertical Line: It is also known as plumb line. It follows the direction of gravity, being perpendicular to the level line at a point.
- Datum: Datum is any surface to which elevations are referred. The mean sea level affords a convenient datum world over, and elevations are commonly given as above or below sea level.
- Elevation: The vertical distance of the point above or below the datum surface is called elevation. Sometimes, the term height is also used for elevation. The difference between elevation between two points is the vertical distance between the two level surfaces in which the two points lie.
- Altitude: It is the vertical distance of the point above mean sea level. If the datum surface is taken as the mean sea level, the elevation is same as the altitude.
- Reduced Level: Reduced level is the calculated height of point above or below the datum. Reduced Level is used synonymously with the term elevation.
- Mean Sea Level: Mean sea level is the average height of sea for all stages of the tides. It is obtained by averaging the height of the water surface of the sea at all the stages of the tides for years.
- Benchmark: It is the point of known elevation above or below the datum. It is used either as a starting point for levelling or as a point to close as a check.

- Station: Station in levelling is that point, where the staff is held. It is the point whose elevation is to be ascertained.

(Punmia et al., 2005) (Punmia et al., 2015) (Roy, 1999)

## 2.2 Study Area

Levelling was carried out in Dhulikhel area premises of Kavre District. Direct (differential) levelling was carried out on a hill named 'Talu Danda'. A permanent benchmark (400-001) was established approximately 100 m north from '28 Kilo', form where levelling was initiated. Levelling was done on approximately 2 km alignment with two PBMs and seven TBMs.

Cross Section Levelling was carried out on the way from LMTC office to Dhulikhel Hospital. It was performed on 405 m alignment at chainage 15 m with lateral distance 3, 6 and 9 m from the longitudinal profile.

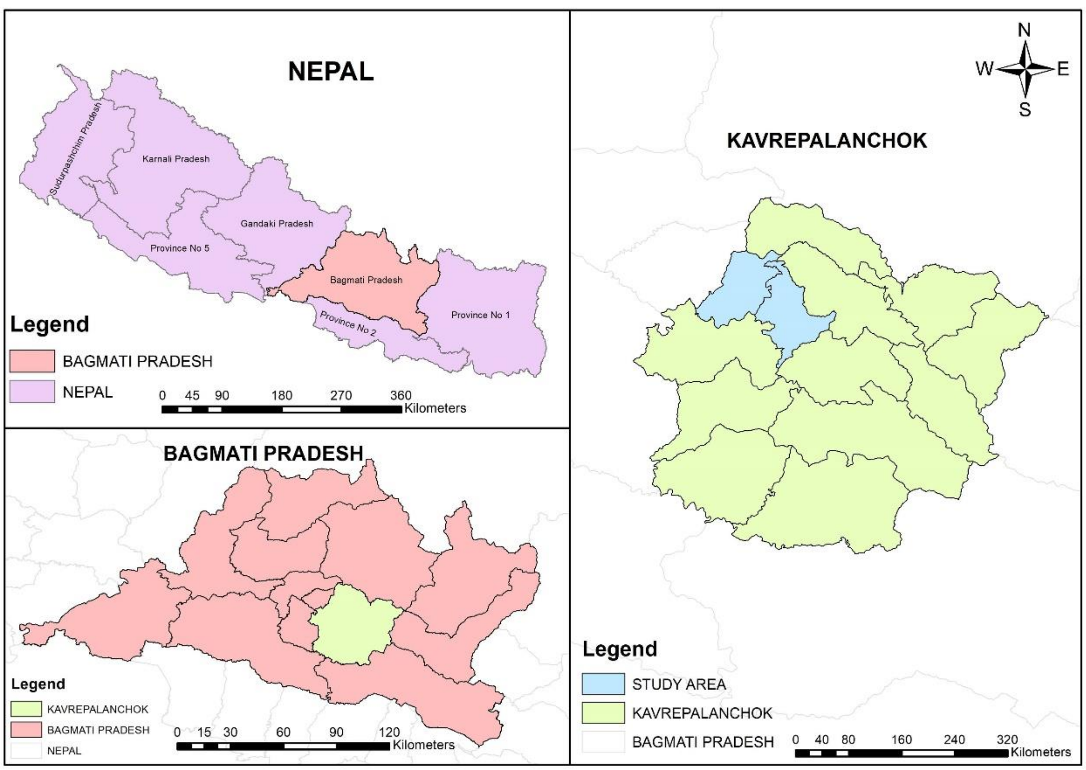


**Figure 4. Map Showing Study Area**

## 2.3 Specifications

i. Order of Work: Fourth Order

ii. Measurement Unit: Metric unit

iii. Level Machine: Auto Level

iv. Staffs used: Telescopic Staff, Self-Reading (5 m)

v. Maximum distance of Line of Sight: 15 m

vi. Maximum Staff Reading: 2.7 m

vii. Minimum Staff Reading: 0.3 m

viii. Linear Measurement: Double Levelling, same instrument and different observer

ix. Collimation Error: 2 mm

x. Permissible Discrepancies: $12.5\sqrt{k}$ mm, k is the distance in km.

xi. Number of Setup: Even

xii. Error Distribution: Distance method

xiii. Observation Time: Whole Day

## 2.4 Study Method and its Workflow

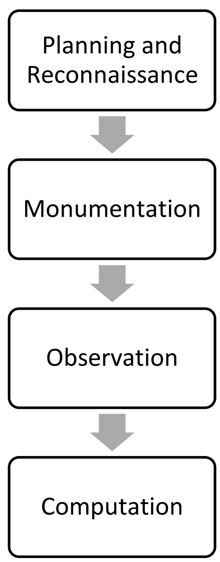


**Figure 5. Methodological Flow Diagram**

### A) Planning and Reconnaissance

Plan about human resources, time availability, instrument resources, area to be surveyed were carried out under the supervision of faculties of the department.

Reconnaissance is fundamentally the first field operation and prominent stage. In this phase, field to be surveyed was fully inspected by one of the members of the project group with the faculties of the department. Position of the stations were noted.

**B) Monumentation**

The noted points during the reconnaissance phase were then marked on the ground. One PBM and three TBMs were monumented on concrete marks using red paint whereas four TBMs and one PBM were monumented with the wooden pegs around the permanent witness structure so that, they could be recovered at any time during the project period.

D-Cards were also prepared for one PBM and two TBMs. D-Card incorporated one reference sketch and other scaled sketch of the location of benchmark. The measurement of benchmark from permanent witness structure were mentioned on the D-Card. Further information like grid sheet number, municipality, land owner, type of monument, direction and dimensions from nearby places, etc were illustrated on the D-Card for the benchmarks.

**D) Observation**

i) <u>Two Peg Test:</u>

Firstly, a Two Peg Test was done to check the accuracy of the line of sight (collimation error). Level machine was setup exactly midway between two points and temporary adjustment was done. Readings (backsight and foresight) were taken on the staffs held at those points and were noted down.

When the level was setup exactly in between two staff stations 30 m apart from each other, following observations were obtained:

B.S reading = 1.405 m, F.S reading = 1.380 m

So, $\delta h_1 = 1.405 - 1.380 = 0.025$ m

The next step was to shift the instrument 5 m away from one of those staff stations and after the temporary adjustment, the staff readings were taken again (having backsight on same staff as previous) and were noted down.

Following observations were obtained:

B.S reading = 1.475 m, F.S reading = 1.415 m

So, $\delta h_2 = 1.475 - 1.415 = 0.060 \text{ m}$

$$\therefore \text{Collimation Error}, \alpha = \frac{\delta h_2 - \delta h_1}{s} = \frac{0.060 - 0.025}{30} = 1.167 \text{ mm}$$

Which lies within the collimation error misclosure, i.e. 2 mm, so accepted.

ii) Differential Levelling:

Rise and Fall method of levelling was implemented. We were provided with the RL of benchmark 400-001 as 1467 m and our job was to calculate the RL of successive established benchmarks. Setting up the level instrument midway between two staff stations, top, middle and bottom staff readings were taken and noted down for both foresight and backsight, which was later used in determining elevation change and horizontal distance between two staff stations in each setup. Double levelling (forward and backward) levelling procedure was implemented to form a closed loop.

iii) Longitudinal Sectioning and Cross Sectioning:

Cross-sections were run at right angles on either side to the longitudinal profile. Elevation of a starting point of the profile line was given and successive elevations at 15 m chainage on 405 m alignment were derived through profile levelling. Meanwhile, elevations of points at lateral distances 3, 6 and 9 m were formulated through cross sectioning.

Graph plots for a longitudinal sectioning and for each cross sections were then developed.

**E) Computation**

From the observed top, middle and bottom staff readings, the mean and sum of those top, middle and bottom readings were computed for each backsight and foresight.

On differentiating the mean reading of Backsight and Foresight for a particular setup, the rise or fall of the topography was derived.

$$\text{If B.S} > \text{F.S, then it is rise, otherwise, it is fall.}$$

The top and bottom staff readings were also used to compute the distance between the setup and the station using tacheometric method.

$$\text{Distance between staff and setup} = (\text{Top reading} - \text{Bottom reading}) * 100$$

After completion of a levelling in forward direction up to a benchmark, arithmetic check was carried out using the computed values that states viz.

$$\sum B.S - \sum F.S = \sum Rise - \sum Fall = Last\ R.L - First\ R.L$$

However, it is recommended to carry out arithmetic check before computing R.L.

If the arithmetic check is found to be correct, then upon completing a loop (forward and backward levelling), the total distance was summed up and tolerance was computed using the formula $12.5\sqrt{k}$ mm where, k is the distance in km. The discrepancy lying inside the tolerable value was then adjusted using distance method as:

$$\text{Correction} = \text{Error} * \frac{\text{Distance between two stations in a setup}}{\text{Total Distance in Double Levelling}}$$

Moving in the similar manner, finally, the height of BM 400-002 was computed and the MSL is 1513.051 m.

*Note:* A computed levelling form is attached in the annex section of this report document.

### 2.4.1 Data Used

We've used the self-measured data collected in the field. However, elevation of the BM 400-001, 1467 m and the elevation of the initial point of the longitudinal profile 1478 m were provided by the faculties of the department.

### 2.4.2 Instruments Used

- Level: An auto-level was used for the levelling procedure. Automatic Level has special arrangement of prisms carried on a pendulum, so that only the horizontal, level rays of light are reflected through the cross hairs to the optical center of the objectives.
- Levelling Staff: Self-Reading Telescopic Staves of 5 m were used.

### 2.4.3 Software Used

Microsoft Excel was used for the calculation procedure.

## 2.5 Measures Adopted for Controlling Error during Levelling

i. Level instrument was setup in the midway between the staff stations to eliminate the consequence of collimation error.

ii. Staff reading of more than 2.7 m was avoided to abolish the error due to non-verticality or trembling of staff.

iii. Staff reading of less than 0.3 m was avoided to abolish the error caused by refraction from the ground surface.

iv. Distance of line of sight was maintained within 15 m for the proper visualization of graduation of staff graduations.

v. Even number of setup and odd number of stations were maintained to eradicate the zero error.

vi. Tilting of the staff in the forward and backward direction was done often to check the verticality.

# 3. RESULTS

Our main target was to establish the vertical control point (z) of the stations. Following were the result obtained:

**Table 1. Computed MSL by Differential Levelling**

| Benchmarks | Distance from previous station (Double levelling) | Reduced Level | Error | MSL Height (m) |
|---|---|---|---|---|
| 400-001 | 000 | 1467 | 000 | 1467 |
| 400-001/1 | 527 | 1502.225 | 0.002 | 1502.227 |
| 400-001/2 | 489 | 1512.497 | 0.003 | 1512.500 |
| 400-001/3 | 360 | 1525.885 | -0.002 | 1525.883 |
| 400-001/4 | 415 | 1554.148 | -0.003 | 1554.145 |
| 400-001/5 | 364 | 1555.325 | 0.002 | 1555.327 |
| 400-001/6 | 259 | 1547.787 | 0.002 | 1547.789 |
| 400-001/7 | 444 | 1545.519 | -0.003 | 1545.516 |
| 400-002 | 544 | 1513.051 | 0.003 | 1513.054 |

Difference in elevation was found to be 46.054

# 4. LIMITATIONS

Hence, we carried out levelling. However, there are some limitations of our project which are pinpointed below:

i. As the specifications for fourth order survey were implemented, it doesn't provide the accuracy of greater than fourth order.

ii. There were not sufficient permanent structures for witness near some of the benchmarks because of which D-Card preparation and relocating them became difficult.

iii. The requirement of frequent setup of instrument in a same place because of busy road traffics might have hampered the observed data in some way.

# 5. CONCLUSION AND RECOMMENDATIONS

Fourth order differential levelling was done for determining the elevation of points with respect to the elevation of a datum. Double levelling was carried out for ensuring the precision of the observed data. From the given elevation of PBM 400-001, 1467 m, the elevation of PBM 400-002 was derived to be 1513.054 m. As a recommendation, it is suggested that, it would have better, if the project were carried out on a less dusty road with less road traffics.

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